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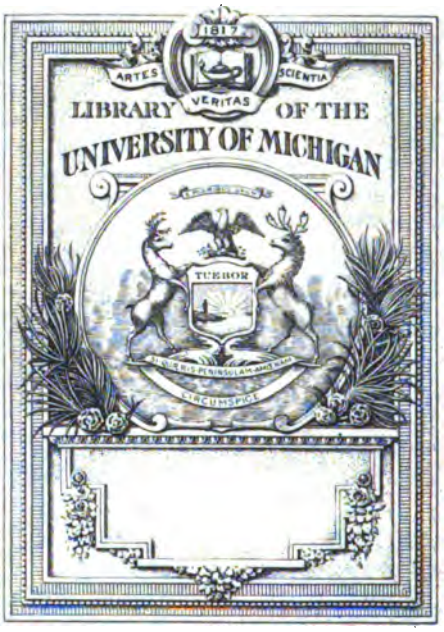
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MUSEUM OF PRACTICAL GEOLOGY
AND GEOLOGICAL SURVEY.

RECORDS

OF THE

SCHOOL OF MINES

AND OF

SCIENCE APPLIED TO THE ARTS.

VOL. I. PART I.

INAUGURAL AND INTRODUCTORY LECTURES TO THE COURSES FOR THE SESSION 1851-2.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE
PUBLISHED BY
LONGMAN, BROWN, GREEN, AND LONGMANS.

1852.

LONDON: PRINTED BY GEORGE E. EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.

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NOTICE.

It is proposed in these "Records" from time to time to publish accounts of researches carried on at the School of Mines, and during the course of the Geological Survey of the United Kingdom. To these will be added occasional notices of such discoveries and researches in Foreign Countries as may be considered important to the progress of the British Arts and Manufactures illustrated in the Museum of Practical Geology.

H. T. De la Beche.

Inaugural Discourse, delivered at the Opening of the School of Mines and of Science applied to the Arts, 6th November 1851.

By Sir Henry T. De la Beche, C.B., F.R.S., &c.

We are this day assembled to inaugurate a system of instruction new to our country; one which does not interfere with existing institutions,—on the contrary, it may be considered as assisting several, inasmuch as while it provides for a want which they do not supply, it refers to knowledge which they teach.

That this establishment should be the means of affording instruction in a particular direction,—an instruction tending more especially to illustrate the application of Geology, and of its associated sciences, to the useful purposes of life, was early decided. In 1839, four years after the first collections were made for the Museum of Practical Geology, the sanction of the Treasury was given to lectures having that application for their object. The system of instruction we commence this day is, therefore, not founded on any new view, twelve years having elapsed since lectures of a similar general character were authorized. That these lectures have not been given has arisen from the want of a proper theatre in which to deliver them, and from the absence of other appliances not, until now, at our command.

Referring thus to the early condition of this establishment, a few words on its origin may, perhaps, not be altogether out of place. It was while (in 1835) conducting the Geological Survey, then in progress, under the Ordnance, in Cornwall, that being forcibly impressed that this survey presented an opportunity, not likely to recur, of illustrating the useful applications of Geology, I ventured to suggest to Mr. Spring Rice (now

Lord Monteagle), then Chancellor of the Exchequer, that a collection should be formed, and placed under the charge of the Office of Works, "containing specimens of the various mineral substances used for roads, in constructing public works or buildings, employed for useful purposes, or from which useful metals were extracted, and that it should be arranged with every reference to instruction;" as, by the adoption of this course, "a large amount of information which was scattered might be condensed, and those interested be enabled to judge how far our known mineral wealth might be rendered available for any undertaking they are required to direct, or may be anxious to promote, for the good or ornament of their country."

The proposal was favourably received, and its object effectually supported by Sir Francis Baring (then Secretary of the Treasury), the late Lord Bessborough (at that time Chief Commissioner of Woods and Works), and by Mr. Trenham W. Philipps, the present Secretary of the Office of Works; from the latter most material aid has always been received during the various changes of administration which have taken place during the last sixteen years. From the statesmen of the different governments who have had this establishment under their consideration since its commencement, we have, without exception, received all kindness and encouragement. As he has passed away from among us, it may be permitted me, without fear of a misconstruction of motives, to refer to the late lamented Sir Robert Peel, as one of those to whom we have been most materially indebted for our progress. He ever expressed a warm interest in our advance, was one of our frequent visitors, and not only by words, but by acts, proved the real interest he took in our success.

As soon as a locality was found for the deposit of specimens*, presents poured in in abundance, and our Cornish mining friends especially may be said, "one and all,"† to have assisted us. The collections, including models of mines and mining machinery, accumulated rapidly. A laboratory, to be alike

* In a house belonging to the Crown, in Craig's Court, Charing Cross.

† The Cornish motto.

useful to the public and the government departments, was added, and a chemist, who was also the curator*, was appointed. The collections continued to augment by the exertions of the Geological Survey, and by presents, so that there was not sufficient space for them in the house first assigned for their reception. An adjoining house, at that time the Earl Marshal's Office, was added to it. This even became insufficient, and a part of the collections was established elsewhere.† Finally, the necessity of proper accommodation became so pressing, especially after 1845, when the Geological Survey and the Museum of Practical Geology were placed under the same department ‡, that—a fitting opportunity occurring—the building in which we are now assembled was erected.

We propose to instruct by means of our collections, our laboratories, our mining record office, our lectures, and the Geological Survey;—thus teaching as well in the field as in this building, and so that the pupils can become practically acquainted with mining in our various mineral districts, be able to study geology, and those of its applications requiring it, on the ground itself, and so unite, in a manner not hitherto attempted, and yet in one for which our opportunities amply provide, a sound combination of science and practice; a combination also kept steadily in view in our laboratories, and in all branches of the instruction upon which it is now purposed to enter.

It may, in the first place, be desirable to call your attention to the objects proposed by our collections. They are not intended to be mere assemblages of specimens, striking either for their brilliancy, colour, or form. In whatever department they may be found they are intended to be instructive with reference to the especial object proposed in that department, and to be employed in illustration of the teaching by lectures

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* The late Mr. Richard Phillips, F.R.S.

† In Whitehall Yard.

‡ The Chief Commissioner of Woods, Works, &c., at that time the Earl of Lincoln (the present Duke of Newcastle).

or other means adopted by those in charge of the different departments confided to them. The collections are arranged for this purpose, and so, also, that the general public, who have free admission to them during the first three days of the week, may readily understand them, by means of succinct treatises on each subject, to be had separately, and at small cost. In them the reason for the presence of the various specimens will be assigned, and it is thus hoped that much useful and valuable information may be afforded.

Let me, in the first place, briefly call your attention to the specimens of the stones applicable to architecture and engineering. This collection is based on one formed during the investigation undertaken in search of the best stone to be employed in the New Houses of Parliament, or the New Palace at Westminster, as the building is often termed. It had become evident that more care than had hitherto been taken with regard to the stone employed in our public edifices was needed, and that public buildings should not be constructed of materials so little capable of resisting atmospheric influences that they readily give way before them, their external enrichments being in some cases defaced even in a few years. We possessed an abundance of different building stones, the durability of which could be seen in various structures in different parts of the country, the quarries themselves could be studied for their capability of supply, and the cost of the transport of the stone furnished by them in different directions could be ascertained. The results of this investigation will be found in the report on the subject presented to Parliament in 1839, and our cases contain the collection then formed. Since that time all diligence has been employed to add to it, care being taken to obtain the information needed; and every specimen has an inscription upon it, showing the edifices wherein the stone has been used, so that the architect can, at a glance, see its general character, and at the same time learn where to study the effects of the atmosphere upon it. A few of our building stones have been employed in illustration of their capability for statuary; thus, excellent copies will be found of the Farnese

Hercules in Portland stone, of the Giustiniani Minerva in Huddlestone dolomite, and of a bust of Antinous, as Bacchus, in Anston dolomite.*

It may, in passing, be of interest to observe that the Normans seem generally to have been very careful in their selection of the stone employed in the erection of their different edifices in this country, as is especially shown in those to which additions have afterwards been made, where we find that they had selected stone, even from comparatively considerable distances, which their successors neglected, employing a far less durable substance nearer the very edifice in which the good qualities of the material used by the Normans were abundantly apparent.

The lower hall, likewise, proves that as regards ornamental marbles, serpentines, porphyries, and granites, our land furnishes an ample supply, and that they are alike remarkable for their beauty and the facility with which they can be procured. It will be observed that they have been, when practicable, arranged so as to produce an architectural effect, thus enabling the architect, and those requiring his aid, to judge of their general appearance, and their application to the purposes thought desirable.

Still, confining our attention to the mineral substances employed by the architect or engineer, the next valuable assemblage of objects embraces the various baked materials which man for so many ages has used for the structures raised by him. This series will be found not wanting in value, and it will be our endeavour to render it instructive. The Jermyn-street front of this building, constructed with Suffolk brick and

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* Reference was made to specimens of different kinds on the table, as illustrating the subject. It was briefly pointed out that building stones might be conveniently divided into, first, those cut by the tool, such as the various kinds of limestone and marble; and secondly, those pounded by the tool, such as a great variety of sandstones, porphyries, granites, and the like. Attention was called, among the former class, to the Anston stone, or dolomite (a compound of carbonate of lime and carbonate of magnesia) employed in the new Houses of Parliament, a stone similar to that used in the Norman front of Southwell church, in Nottinghamshire, the tool marks on which are nearly as fresh as when it was first erected.

Anston dolomite, is intended to illustrate the intermixture of two valuable materials,—the one natural, the other artificial; and it will, at some future time, be interesting to observe the relative resistance presented by each to atmospheric influences.

Our ceramic collection is extensive, and, of its kind, unique. Especial reference is made in it to the materials and forms employed in the ceramic manufactures of this country from early times. The Staffordshire series reaches as far back as 1500, and is brought up to the present time, the last additions being objects shown at the late Great Exhibition of the Industry of all Nations. This series is based on a collection made in Staffordshire by Mr. Enoch Wood, than whom no one could be more capable of selecting the best illustrations of the progress of the Staffordshire Potteries. In the hall will have been observed a tesselated pavement, designed after portions of those in a Roman villa, at Woodchester, in Gloucestershire, and formed of compressed clays, afterwards baked, by a patent process, a beautiful illustration of progress in this kind of manufacture.* The other English porcelains and earthenwares, such as those of Chelsea, Derby, Plymouth, Worcester, and Swansea, are also represented by carefully selected examples, so as to illustrate their history, the circumstances connected with the materials used, and the forms adopted. I may point to the specimen showing the earliest transfer of prints to porcelain, by Dr. Wall, with the date of 1751, as exemplifying attention to the history of this branch of industry; while, as you will observe, another specimen,—a Staffordshire one, however,—shows the present state of this kind of transfer. In the first case only one colour was imprinted on the porcelain; in the second numerous colours, forming a picture.

The vitreous series will likewise be found one presenting

* Water, as employed usually in ceramic manufactures, may be regarded as a mere tool, by which the material is easily worked. It has to be removed as much as possible by evaporation, before the firing is effected. The tesseræ alluded to in the text are made with materials nearly dry, with only sufficient moisture to cohere when pressed. Thus they are very dense, from the heavy pressure to which they are subjected, and remain so even after baking.

much interest. This also is arranged historically, and at the same time with reference to materials, and mode of manufacture. In this series we have to pass through Venetian, Roman, Greek, Egyptian, and Assyrian glass for proper illustration. The collection has been found alike interesting to the classical student and the modern manufacturer. The analyses that have been already made of some of the glass are highly illustrative in both respects, and these researches will be further prosecuted.*

We now reach the mining collections. The metallic series is arranged so as to show the various ores of the different metals, their mode of occurrence in the earth, the methods employed in their extraction, and the means used for rendering them marketable. At this point the labours of the miner terminate, and those of the metallurgist commence. These are also fully illustrated, and the qualities of the different metals, either alone, or mingled as alloys, in their application to arts and manufactures carefully exhibited. In the department of the ores it became needful to include not only those from our colonies (attention to our colonial products being one of the objects of this institution), but also those of many foreign lands, in order to accustom our miners to kinds and modifications of them, with which they are not familiar. Those who have during many years watched the progress of our mines will be fully aware how essential this may be to their effective progress. It is well known that large sums of money have been from time to time lost from a want of this knowledge, quantities of strange ores having been washed down rivers, or into the sea, before their value was known. A recent instance may illustrate this point. Ores, regarded only as important for the copper they contained, were raised on some property of the Duke of Argyll, in Scotland. After a time the works were abandoned, as the copper found in the ores was not sufficiently abundant to pay for the cost of obtaining them, and much was thrown aside as not worth dressing. The Duke

* For example, the Roman glass, found near Naples, seems to have a common character, and to be formed, as chief ingredients, of the silicates of lime and soda, the latter probably derived from the natron lakes of Egypt.

impressed with a certain character in the ores, brought specimens to this institution for analysis, when it was found that they contained 11 per cent. of nickel, a valuable metal, and, as you are aware, extensively employed at this time in different alloys, such as those known as German silver. Other portions have been found still richer in this metal, and the ore thrown away and dispersed has been valued at from 30*l.* to 40*l.* per ton. It may be added, that even after this ore was thus found to contain nickel, it was stated, from an assay elsewhere, not to afford this metal; so little diffused is effective metallurgical knowledge in this land.*

Both the composition of ores, and their mode of occurrence, involve questions of high scientific interest, bearing upon practical applications of great importance. Let us for a moment regard the accompanying diagram†, representing a proportional and sectional view of our earth, with the atmosphere, and a hundred miles beneath the surface of the sea; of the matter really at that depth we know nothing, but it is convenient, as showing that if we did possess that knowledge, the portion of the earth then known would be exceedingly small. As far as we are acquainted with the rocks upon the surface of our spheroid, they are formed of various oxides of different substances, supposed simple. The exceptions, as regards the general volume they occupy, are insignificant. In certain cracks, fissures, or other cavities in this mass of oxides, we find matter under other conditions, derived probably from beneath, and, as it were, affording something of an insight into substances there more abundantly occurring. There may be secondary conditions of the same substances, but still the inference remains that these fissures and other cavities may afford, by careful study, information in the direction mentioned, and it is important to remember that while the mean density of the surface of the earth is taken at 2·6, that of the whole mass is inferred to be

* Even within these few days a case has occurred in Devonshire where a field wall was constructed of grey copper ore, and the breaking of a gate post led to a knowledge of the fact. This happened in a mining district.

† Referring to one exhibited.

4·39, pointing to heavier matter inwards, whatever views we may entertain of the diminution of density produced by heat in the interior.

At first sight the practical value of such an inquiry may appear very remote. It is, however, like all investigations in high science, one which may bear fruit if properly followed out. We have, in the first place, to couple it with the observed modes of occurrence of the ores of the metals in fissures and other cavities, and carefully study why it happens that given conditions produce given results; as, for example, why it is that in Derbyshire,* where the same fissures traverse different rocks, only certain of them have, as it were, permitted the accumulation of lead ores near them, while others, as a general fact, have repulsed them. Such facts are not new to the miner; he is familiar, in different districts and lands, with the modifications and changes observed in the assemblages of ores of all kinds in contact with various rocks in the same range of fissures. The cause of these facts is an object of science, and already progress has been made; when found it becomes a guide of the highest importance to the practical miner.

Our collections of the mode of occurrence of the ores are very extensive, and great care is taken to make them effectively instructive. As to the methods of their extraction, models and drawings of various kinds show not only the different machines used for draining mines, but also the mode of raising the ores. Great attention is given to this subject. So also with respect to the dressing of the ores, the like regard to proper illustration is paid.

The metallurgical series contains examples as well of foreign as of our own methods of reducing the metals. Our cases are full of objects of interest in this department, as well as of illustrations of the uses of the metals, and of their compounds or alloys in arts and manufactures, including an electrotype series of much interest. The ductility of copper, as shown in the specimens on the table, and as formed into the elegant vessels

* Pointing to a diagram on the wall.

exhibited, will illustrate the manner in which this subject is treated, as will also the statuettes before you, formed of bronze composed of the alloy which our analyses have shown to be that most effective for casting figures, and which is, at the same time, one that the Greeks and Romans seem to have adopted.

Quitting the metalliferous series, we may mention that the methods of working coal receive ample attention, due regard being had to that important object, the ventilation of collieries. Indeed we endeavour to be as complete as possible in all things illustrative of the working of mines, of whatever kind these may be, and are not neglectful of a variety of mineral products, such as rock salt, sulphur, alum, plumbago, and the like, which it would be out of place further to notice.

Our very important and valuable palæontological collection should nevertheless be specified, since it may be regarded as the most perfect of its kind: it is the joint result of the labours of the Geological Survey, and of a mass of presents, even of whole private collections. Of the value of such collections it would be superfluous now to insist, since, as you are aware, all mining schools strive to possess them in as extended a form as possible; those who desire and support such schools being fully sensible of their important bearing on geological investigations, and consequently on the practical applications of geology. Did time permit, it would be easy to show how many mistakes have been made, especially in seeking for coal, thousands having been thrown away in a vain search for that which a very moderate acquaintance with palæontology would have prevented.

Donations to our collections have been again mentioned. It may be here observed that the larger portion of them are composed of presents, showing, as we hope, that the public are not dissatisfied with our endeavours to be useful. From the Great Exhibition alone the donations we have received must already have reached a value of not less than 3,000*l.*, and these presents have not yet ceased.

Passing over the series illustrating the formation of rocks at different geological times, and of the changes which have taken place in them since their deposit, many of which have practical bearings,—as, for example, the roofing slates formed by the

action which has been termed *cleavage*, and which so distinguish themselves for durability from those obtained by the simple lamination of rocks, corresponding with the planes of their deposit,—we come to the Mining Record Office.

This office was established in connexion with the Museum of Practical Geology in 1840. It was so for the purpose of collecting information respecting the distribution and produce of our mines,—and for procuring plans and sections not only of modern workings but also of abandoned mines,—the last especially important, as being the means of saving life, or the erroneous outlay of capital, by preventing new works from being carried on in wrong directions. It is but right to remark that we have always received hearty co-operation from the mining interest in carrying out the objects of this office. To illustrate the value of the plans and sections of abandoned mines, let us select from those on the wall before us a section of Wheal Alfred, Cornwall. It had been stated that the working of this mine, at one time a most prosperous one (having afforded a profit of 140,000*l.*), had ceased on account of much water, which the engines of the time were supposed not equal to raise. A company was about to be formed, when it was suggested that documents known to be in our Record Office should be examined. The section before you at once pointed out, by the prices of work entered upon it, that the mine had been abandoned for its poverty, the undertaking was in consequence dropped, and a large useless outlay of money avoided. The section is the present of Mr. John Taylor, to whom the Mining Record Office is most especially indebted for numerous and important documents of the like kind.

From the aid also afforded by those interested we are gradually acquiring more real information respecting the products of our mines than has been hitherto procured; a subject alike important for the miner and the public. The copper ores raised have long been well ascertained, and the same may be said for the tin, even now that the "tin coinage" of Cornwall and Devon has ceased. We have been enabled to produce lead returns during the last four years, of an accuracy not before known. We are now proceeding with the other metals and

coal, and hope, at no distant date, to produce effective returns of these also.

The laboratories, one for general chemistry, the other for metallurgy, and their bearing upon a School of Mines and of Science applied to the Arts, may be said to speak for themselves; their usefulness and importance are evident. A special metallurgical laboratory has not been previously attached to any place of instruction in the country. With regard to the work executed at these laboratories for the public service, we may point, as one of the last of our endeavours to be useful, to the inquiry undertaken for the Admiralty as to the coals of this country best suited to the steam navy, three reports on which, completing the investigation, have been presented to Parliament. It will be obvious that to obtain the greatest amount of locomotive power from the smallest volume of fuel, and to avoid the evolution of smoke, are points of no slight importance for our steam navy.

As it is contemplated that our students should avail themselves of the Geological Survey for field instruction, including actual mining, it may be desirable, perhaps, to call your attention to certain of the maps and sections constructed by that survey, and now before you, inasmuch as, while they refer to geology as a science, they are at the same time available for its industrial applications. Thus you will observe that all mineral veins and the outcrops of coal-beds are inserted on these maps, as well as the boundaries of the various rocks, and with the exactitude required. The sections, in like manner, show the mode of occurrence of the coal and ironstone beds in certain districts, and of the mineral veins in others.

A point of much interest, both in its scientific and practical bearing, is now engaging the attention of the Survey in central England, namely, the probable depths and chances of obtaining coal beneath the red sandstones and marls there so abundant. There is reason to consider that, notwithstanding the many difficulties with which the subject is surrounded, very considerable advance has been made in this direction.

That the applications of such a survey are not confined to mining, you need scarcely be reminded; its aid to agriculture

and engineering are equally important. Our every-day's experience along coasts shows us how needful it is that the engineer should, as well as the geologist, study them. Let us, for example, consider this cove*,—there are hundreds such as it to be found on our coasts. The mode in which it is silted up is apparent to you, and yet many an artificial cove has been constructed, at great cost and loss, which was as certain to be filled up by silt and sand as this has been and must be. No doubt there are conditions where the silting up may be so small as to be comparatively unimportant, but the probability of these conditions requires the study pointed out. While on this subject, let me also briefly call your attention to the silting up of estuaries. Those who are engaged on the Geological Survey have often to consider it both with reference to the mode of deposit of certain rocks, and to the changes effected by it at the present day. The plan before you shows an estuary with the boundaries of high and low water, a spit of shingles running in front of part of the estuary, separating it from the sea, and the comparatively narrow entrance for the ingress and egress of the tide. The whole is the result of the balance of certain conditions by which the channel from the sea to the estuary is kept clear, and vessels of a certain class can enter and depart. The body of water entering and passing out is important; and yet what do we often find done, and done too by Act of Parliament? The body of water entering, and consequently passing out, is diminished for the purpose of *reclaiming*, as it is termed, certain mud-banks, often extensive; thousands of tons of water are thus sometimes cut off from performing the work by which they aided in keeping the channel to the sea clear; the bottom of the channel rises, and the port is damaged. No doubt the mudbank may be converted into fertile land, but at what loss! The natural causes for deteriorating estuary harbours are often bad enough, but why artificially strive to injure them? Other examples of the application of geology to engineering and the useful purposes of life generally might be readily

* Pointing to section on the wall.

adduced; these, however, may suffice to illustrate their importance.

Although the raw mineral produce of Great Britain and Ireland is valued at 24,000,000*l.* per annum, or about four ninths of that of all Europe, including these islands (the coal estimated at the pit mouth, the iron in the pig, and so on), there existed until now no means in this country for affording needful instruction to those who thus raise so great an amount of mineral matter, to be afterwards employed in affording occupation to an additional and large part of our population; all was left to chance, and the result is well known. Many who can afford it go to other lands to study in the mining schools provided by their governments; some fight through their difficulties at home, becoming valuable and useful men; while the mass of our miners remain uninstructed, except so far as they can pick up practical information from each other in the mines, seldom being conversant but with such things as they can find in very limited districts, little aware of what others may be doing in their own calling elsewhere. The diagram exhibited will show you the relative proportions of the annual mineral produce of the different European countries,* in nearly all of which, except Great Britain, mining schools are established, those states being fully aware of the effective researches they promote, and the waste of money they prevent. Are our miners less deserving of attention than those of other lands, or are they supposed so dull and disinclined to knowledge as not to be capable of profiting, as well as the miners of other nations, by instruction? Let those who thus believe visit our mining districts, espe-

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* This diagram represented the mineral produce of the different European states by proportional lines. This produce is usually estimated as follows:—

Great Britain	1	Hartz	$\frac{1}{12}$
Russia and Poland	$\frac{2}{7}$	Tuscany	$\frac{1}{31}$
France	$\frac{1}{4}$	Bavaria	$\frac{1}{33}$
Austria	$\frac{2}{13}$	Saxony	$\frac{1}{34}$
Spain	$\frac{1}{8}$	Piedmont and Savoy	$\frac{1}{38}$
Prussia	$\frac{1}{6}$	Denmark	$\frac{1}{49}$
Sweden	$\frac{2}{19}$	Norway	$\frac{1}{55}$

cially such as are metalliferous, where the miner has so often to gain his daily bread by the exercise of his judgment, and they will speedily be undeceived. They will find men as able and willing to profit by instruction as elsewhere in our land. They will see many with powerful minds who have risen from amid all their difficulties, adding continually and greatly to our stock of practical knowledge, but who yet would evidently have accomplished far more, if, in their early day, they had possessed the advantage of starting with the knowledge of the time applicable to their pursuits. It is to be deplored that so much of the mass of important facts known to such men has been lost from the want of a system by which it could have been preserved for classification and use in further advance. Too much has perished with the remarkable men who have from time to time appeared in our mineral districts.

Seeing the large proportion of the mineral wealth of Europe furnished by the British Islands, it might, perhaps, be inferred from a superficial view of the subject, that a mining school, such as we propose opening this day, is useless. Very slight investigation will soon place this matter in its true light. The natural advantages, especially as regards the mode of occurrence and abundance of coal and of iron,—the cheapness and good qualities of which enable so many other industries to flourish,—are great in our land; iron and coal can be easily procured, worked, and retained for home use or exported, as may be thought advisable. These advantages are by no means possessed in like manner by other countries in Europe. Far from it; indeed, in several it is only by a most careful application of science and practice, and by seizing every discovery that can be turned to account, that profit can be effected. If the same indifference to general knowledge there existed as is permitted among us, the mineral produce of many of these states would be greatly diminished, and in some cases the mining in certain districts might even, to a great extent, be suspended, until new discoveries in science might enable successful operations to be carried on. For example, within the last three years, in Reichenstein, Silesia, certain mines, after remaining idle for five centuries, were, by a new method of Professor Plattner for obtaining gold from poor auriferous ores,

enabled to be again worked for gold, and with considerable profit.

Looking at our mineral produce, the great and chief mass is composed of our coal and iron. We raise the largest amount of both among the nations of the world; not that we possess the largest amount of coal in any land,—in this respect the United States of America far surpass us. The working of it, however, remains to be developed by them. The more need, therefore, that by skill on our part, and by not neglecting the application of knowledge which may bear upon it, we should not permit our advantages to escape. As regards fuel, what would man be without his power to produce and use fire? Remove this power, and what happens? How far could he range towards the colder regions of the earth, either as regards elevation in the atmosphere, or towards the poles? He must be a fire-making before he can be the cooking animal, which he is sometimes termed. Taken with iron, the great metal of civilization, his fire-making power is rendered immensely advantageous for his advance and well-being. Cheap heat and cheap iron are, therefore, among his important wants. While this country possesses the power to produce both, let not that power be wasted,—let science and practice be so combined, that the largest amount of both may be secured, and the future be regarded as well as the present.

The amount of coal annually raised in Great Britain (comparatively little is supplied by Ireland) is estimated at more than 35,000,000 tons. It probably much exceeds this amount; but taking that number of tons, 2,800,000 tons* being exported, 32,200,000 tons remain for household consumption, and for application to our various industries. London alone consumes nearly 3,500,000 tons of coal. No wonder we have a smoky metropolis.

With regard to iron, Great Britain has made remarkable progress within the last century. In 1750, only 30,000 tons of that metal were raised in it. In 1850, 2,250,000 tons of

* The quantity of coals, culm, and cinders exported in 1849 was 2,827,979 tons.

iron were produced. It is somewhat difficult, by means of official returns, to obtain the exact equivalent in tons of pig-iron exported, but we find the value of the iron export in 1849, including pig and bar iron, iron wire, and various kinds of wrought iron, taken at 4,245,049*l.** Iron, therefore, of many millions in value remains for our home consumption, applied in various ways to our national industry. Tin should not be omitted as among our important British metals, seeing that it is raised to the amount of about 400,000*l.* annually; neither should our copper be forgotten, since that of Cornwall and Devon alone may be valued at nearly 900,000*l.* annually. With regard to copper and tin in that district, (British tin is alone found there,) of the former it yields one-third, and of the latter nine-tenths of the whole supply from the remainder of the British islands and all the other countries of Europe. As to tin, the quantity taken from Cornwall and Devon from the time of the Phœnicians must have been enormous, seeing that until of late years it seems to have supplied nearly the whole of the European demand.

It has been mentioned that no institution existed, other than that we now propose to establish, in which the instruction so beneficial to our miners could be afforded. It, however, should not be forgotten that Sir Charles Lemon, ever alive to the progress and well-being of his native county, Cornwall, did, in 1838, establish at his own cost a mining school in it, being desirous of showing the importance of such an establishment. He continued this school for two or three years, and offered to place a considerable sum of money—10,000*l.*—at the disposal of the county, if it would add the like sum, to found a proper school of mines in Cornwall. Circumstances at the time prevented this important object from being carried out. There would, however, appear to be a movement in that district in the direction of such a school. Let us hope that it will continue, and be productive of a fitting establishment of the kind. There are also indications of the like movements in other mineral districts.

* This does not include steam engine machinery and mill work, the value of which, exported in 1849, is given as 709,071*l.*

May the endeavours of those who thus search to benefit our mining population by instruction be successful. The means of the greater numbers of that population will alone enable them to obtain instruction when brought to their doors. Surely it would not be over difficult, properly weighing all local conditions, to afford those who execute even the ordinary work teaching of an order which should be highly beneficial to them. How many lives would be saved in our collieries if but a fair range of information were afforded to those who too often have the lives of so many of their fellow-workmen in their power. In the examinations which have so frequently been instituted on the spot into the causes of explosions in our collieries, and in which I have had but too often personally to take a part, how constantly the frightful truth is forced upon us that folly and foolhardiness, founded on ignorance, have destroyed numbers, even to the amount of seventy and more, at one blast, and that every day hundreds of those who labour for our comfort or our profit are at the mercy of ignorance.

Let us hope that district instruction may soon commence, and that those who locally distinguish themselves by the application of their abilities may find in this institution, free of cost, the means of still further advancing themselves. Let opportunity be afforded to all for obtaining the knowledge which their course in life may require; shut out none from the chance of becoming pre-eminent. The history of the greatest discoveries teaches us, that it is not always by the rich that mankind have been advanced.

As far as may be in our power, we propose to explain by evening lectures to the working men of London, those really engaged in business, and whose good characters can be vouched for by their employers, such parts of our collections as may be thought to be usefully interesting to them. Some slight payment may be required, sufficient to prove that those attending desire to do so. At the time when our collections are open gratuitously to the public, the working man is usually engaged in his occupation; and yet to him we have much to show,—much that may be important to him in his calling. We trust therefore to aid him and consequently the public for whom he labours,

by endeavouring to convey instruction of the kind mentioned; an instruction which, as far as it may extend, those probably who have carefully considered the bearings of the late great Exhibition will not fail to view as an advance in the right direction.

In thus endeavouring to place before you, in a short address, some of the points which it appeared desirable to notice, I have felt so much embarrassment from the abundance of the riches at command, that in choosing subjects, many, perhaps, even of importance, may have been omitted. I pray you, therefore, carefully to examine the bearings of the subject by yourselves, feeling confident that you will come but to one conclusion, the necessity of the institution we inaugurate this day.

It will be the duty of my colleagues, charged with teaching the different branches of knowledge mentioned in our programme, each to point out, in an introductory discourse, the subjects which he may consider most worthy of attention in his science, whether viewed strictly as such, or in its application for the use and well-being of man.

It would be trespassing too far upon your time to occupy it with details and inferences which will be so much better laid before you by my colleagues. A few words, however, may not be out of place as to the useful applications of science generally, since the name borne by this institution really refers to several.

Geology, as now usually regarded, and as a whole, may be considered as a group of, at least, portions of different branches of knowledge, added to researches peculiar to itself, rather than as alone forming a science so distinct as to require only minor aid from others; this grouping, at the same time, presenting a most definite character, so that geology cannot be confounded with other branches of knowledge. In this, it may indeed, not very materially differ from some of those, once considered more separable from each other than modern discoveries will permit us now to view them; the mutual relations of several differently named sciences having been found greater, as a more profound knowledge of them has been obtained. Geology is, nevertheless, one among them, requiring such direct aid from several sciences, as to stand out somewhat

prominently, as is shown by the division of labour which has, of late, so much occupied the attention of its cultivators. Thus we have seen it requiring, and obtaining, the assistance of the mathematician, the astronomer, the physicist, the mechanician, the chemist, the mineralogist, the zoologist, and the botanist.

In applying such a branch of knowledge, it therefore, becomes important to view it as of a mixed kind requiring a corresponding system of instruction; its applications also requiring teaching in given directions, so as to embrace the conditions arising from the applications themselves. Hence the instruction proposed to be carried out at this institution is divided into various heads, so as to have reference not only to the miner and manufacturer, but also to the agriculturist, the architect, and the engineer, and so that the subjects taught should also be viewed in connexion with those arts to which they may be applicable.

In these days, when ocean steamers, railways, and electric telegraphs are transporting man, or his thought, from region to region, with a certainty and despatch not deemed probable even a few years since, and when a great Industrial Exhibition has just closed after a most brilliant career—an Exhibition which could not have existed without these and similar aids to the progress of mankind, it might appear superfluous to point to any applications, even those of the highest sciences, as contributing to the well-being of our kind. We still, however, too frequently hear of practical knowledge as if in a certain sense opposed to a scientific method of accounting for it, and as if experience, without that advantage, were more trustworthy than the like experience with it. Such may not, certainly, be the actual expressions; but the usual reasoning adopted, nevertheless, too frequently amounts to the same view.

Let it not for a moment, however, be inferred that we do not regard practical knowledge as of the highest importance, even in cases where those possessing it may not also possess the power of satisfactorily analysing it. Facts brought to light by practice are to general progress that which experiments are to experimental philosophy,—they have to be properly explained by the best methods at command, after they have been satisfactorily proved to be facts; a matter of no slight impor-

tance, seeing that so many things, so termed, are not such, We only desire that all interested should have the power to discriminate between sound and unsound views, so far as existing knowledge may be available,—taking all care not to neglect or depreciate the information afforded by those whose opportunities may not have sufficiently advanced their power to analyse and extend it. We should recollect how rapidly the science of our time has increased among the most instructed, and with it the power of its extension and application in directions not dreamt of by our forefathers. As some reason, right or wrong, is sure to be assigned for every practice, it is most important that those connected with it should possess the existing knowledge upon which it rests. It becomes a national duty to assist in collecting that knowledge for them, especially when widely scattered. For the purposes contemplated at this establishment, facts, bearing upon the teaching proposed, are to be sought far and wide, among various other nations as well as in our own. That there is an increasing feeling among those most interested, that successfully to apply a science requires both a knowledge of that science and of the subject to which it is to be applied, and that wherever there is a want for promoting the combined information it should be supplied, our every day experience shows.

Those whose duties or inclinations take them among our industrial population can scarcely fail to observe how much the term *practical* is becoming appreciated in its true sense. Indeed, the difficulties which the instructed in that population have to contend with from the uninstructed can scarcely otherwise than lead to correct views on this head. It is the duty of all to assist in affording to those whose minds are alive to every application of knowledge the power to acquire that which they are desirous of applying, so that they may possess the means of analysing their practice successfully for general progress and the public good. The more real knowledge is diffused, the more will effective practice be increased. Science and practice are not antagonistic, they are mutual aids. The one advances with the other. Civilization advances science, viewed in all its strictness and height; and science, by its applications,

advances civilization. Steadily bearing in mind these truths,—as we conceive them to be,—it will be our earnest endeavour at this institution to be useful, as far as our powers and abilities may permit, in promoting the progress of those for whom our teaching has especial reference; trusting, at the same time, to supply a national want, and, by so doing, assist in advancing the general good of our country.

The Study of Abstract Science essential to the Progress of Industry. (Being the Introductory Lecture to the Course of Chemistry.)

By Lyon Playfair, C.B., F.R.S.

The raw material used by Industry for the production of useful objects doubtless forms the basis of manufactures, but possesses a fluctuating value in relation to that of the object into which it is converted. In the successful prosecution of manufactures, apart from the influence of capital and labour, two elements are involved, each forming a factor which in a competition of Industry may be made to assume very different values. The first element is the raw material; the second, the skill and knowledge used in adapting it to the purposes for which it is designed. In America, cotton being indigenous, is cheap; and fuel, the other raw material employed in its conversion to a textile fabric, is not expensive. In England, the same cotton is much dearer, but the fuel may be assumed to be equal in price. The competition between the two countries, in respect to calico, resolves itself into the necessity that England, to overcome the disadvantage of the increased cost of the raw material, must infuse a greater amount of skill and knowledge into the processes employed in its adaptation to useful purposes. England has succeeded in doing this; and, consequently, the mills of Manchester may render unproductive the

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Note.—Some years since, I gave a lecture, never published, though a few copies were printed for private circulation among my students, the subject being similar to this. A demand having been made for it by publishers, as expressive of a want now acknowledged by manufacturers to exist, I have preferred taking this opportunity to write a new lecture on the same text, incorporating some of the passages of the former lecture.

mills of Lowell. But reverse the conditions of the two countries, and a similar result attests the truth of the same principle. Sheffield produces steel, which is exported in large quantity as a raw material to America. The history of that country has created a knowledge of the conditions required for the manufacture of edge-tools. The forests were not cleared, or the prairies converted into arable land, without that observing nation understanding the qualities and the requirements of the axe, the adze, and the spade. The knowledge thus attained was applied to the manufacture of edge-tools; and America returns to England its own steel, but under a new form, and endowed with an excellence, a temper, and a cheapness yet unattained by our artisans. Without this application of greater skill it would have been impossible for America to have competed with the country producing the raw material.

A nation, if it combine ordinary intelligence with its local advantages of cheap raw material, may long preserve almost a monopoly in special manufactures, and will continue to do so, either until the competing nation has risen so high above her in intelligence as to make this more than an equivalent for the local advantage of the other, or until a greater equalization in the price of the raw material renders a small amount of superiority in the intellectual element of sufficient importance to secure successful competition.

But should any great transition of the world take place by which local advantages were levelled, and the raw material confined to one country became readily attainable by all at a slight difference in its cost, then the competition in industry must become a competition in intellect; and the nation most quickly promoting the intellectual development of its artisans must, by an inevitable law of nature, advance; whilst the country neglecting its industrial training must as inevitably recede.

It requires no mental acumen to perceive that we are rapidly approaching to, if we have not yet arrived at, this period of wonderful transition, when nations must speedily acquire the levels due to their different amounts of intellectual development.

It is quite true that a superabundance of capital may for a time preserve a country from a quick depression, even should it lapse in its intellectual training; but the support thus given can only be temporary and illusory, for if, by the purchase of foreign talent, the necessary knowledge be infused into home manufactures, this can only have the effect of raising the intellectual element in the foreign country, and thus finally accelerate its success as a competing nation.

There never was a time when it was so necessary as now that skill and science should be united for the promotion of the industrial arts. At former periods of human history, local advantages or accidental combinations were the foundations of a nation's prosperity. The time is not distant when it was thought that the possession of mineral fuel indicated a country as the natural manufactory of the necessaries of life employing machinery for their production; while the existence of large tracts of land, warmed by a genial sun, stamped another nation as essentially agricultural, and employed its population in the labours of the field. Each country fell into a routine of manufacture; and Italy and France produced their silks and shawls, with as little thought of competition as England its machinery and calicoes.

Science in advancing has created resources unthought of before, and has removed the local barriers opposed to the progress of Industry. Countries were no longer confined in their aspirations by smallness of territory, for this by the aid of science enlarged its powers. The country able in its agricultural poverty to support only a scanty and miserable population, expanded itself for the reception of increased numbers as the produce of its land augmented, and thus knowledge, in the improvement of agriculture, won by a bloodless victory vast additional territory to aid in the industrial resources of the nation; for a land, with a twofold increase in agricultural production, has, for all practical purposes, unfolded itself to twice its size. Science in its progress was improving and simplifying processes of manufacture, while it was opening at the same time a communication between the nations of the earth. The amazing facilities of transport afforded by the introduction of steam

enabled a ready interchange of their natural riches; and mere adventitious local advantages, apart from skill and science in their adaptation, became of much less moment than they formerly were. The proof of this is in the fact, that the staple manufactures are now carried on in all parts of Europe, and that there is a constantly increasing and active competition of most of the great nations in all the markets of the world. If England still continue in advance, it will not be from the abundance of her coal and iron, but because, uniting science with practice, she enables her discoveries in philosophy to keep pace with her aptitude in applying them.

But is it true that England does act thus wisely; and is it true that science does hold in this country its just position in public esteem, or that it is fostered sufficiently to make that progress which it is now doing in other lands? To all such questions a negative reply must be given; for beyond a theoretical recognition of the importance of science in its relations to practice, and the establishment of this museum and college —a very important measure, I admit—the state and the public only look to the empirical result, and have not deemed it necessary to foster the knowledge producing it. But England is the only European state thus blind to its own interests, and not yet thoroughly awakened to the importance of giving an intellectual training to those intrusted with its manufactures. This is proved by the large endowments given by foreign governments for the support of institutions connected with Industrial Science, and it finds expression in the writings of their thinking men. "An equal appreciation of all parts of knowledge," says Humboldt, "is an especial requirement of the present epoch, in which the material wealth and the increasing prosperity of nations are in a great measure based on a more enlightened employment of natural products and forces. The most superficial glance at the present condition of European states shows, that those which linger in the race cannot hope to escape the partial diminution and perhaps the final annihilation of their resources. It is with nations as with nature, which, according to a happy expression of Goethe, knows no pause in ever-increasing movement, development, and production—a curse still cleaving to standing still.

"Nothing but serious occupation with Chemistry and natural and physical Science can defend a state from the consequences of competition. Man can produce no effect upon nature, or appropriate her powers, unless he is conversant with her laws, and with their relations to material objects according to measure and numbers. And in this lies the power of popular intelligence, which rises or falls as it encourages or neglects this study. Science and information are the joy and justification of mankind. They form the springs of a nation's wealth, being often indeed substitutes for those material riches which nature has in many cases distributed with so partial a hand. Those nations which remain behind in manufacturing activity, by neglecting the practical applications of the mechanical arts and of industrial Chemistry, to the transmission, growth, or manufacture of raw materials—those nations among whom respect for such activity does not pervade all classes—must inevitably fall from any prosperity they may have attained; and this by so much the more certainly and speedily as neighbouring states, instinct with the power of youthful renovation, in which Science and the arts of Industry operate or lend each other mutual assistance, are seen pressing forward in the race."

It is but the overflowings of science that thus enter into and animate industry. In its study we are never sure that the morrow may not gladden the world with an application of a principle to-day abstract, and apparently remote from practice. This is a truth above all things necessary to convert into a living faith the minds of those who devote their lives to its practical applications. Nothing is more erroneous in their case than to neglect the acquisition of abstract scientific truths because they appear remote from practice. I do not admit that it is even wise to address to oneself the question *cui bono?* Science is too lofty for measurement by the yard of utility;—too inestimable for expression by a money standard. These grovelling ideas of the objects of science, which constantly jar it in its intercourse with the world, ought to find no response in the breast of any devotee who would draw inspiration from its shrine. But whilst I protest against the indulgence of a mere utilitarian appetite for science, I think it infinitely advan-

tageous to examine it in its practical relations to life; but it must not be forgotten, that though the object of industrial study is to view science in its beneficent overflowings of kindness to man, these material benefits arise from the very fulness of its measure. If we revert back to the intellectual wanderings of science in its search for truth, it becomes surprising how soon it shook off the trammels of ignorance, and developed into a glorious liberty. Let us recollect how much science has advanced within the last three centuries, and even her past history becomes more remarkable in its progress than the present. It is no mean task for intellect to leap over the barriers of ignorance; it is even more easy to go onward in new and untrodden paths. It was only at the end of the sixteenth century that the Council of Sages at Salamanca negatived the idea of a western continent, by the writings of Lactantius. "Is there any one so foolish," says he, "as to believe that there are antipodes with their feet opposite to ours; people who walk with their heels upwards and their heads hanging down? That there is a part of the world in which all things are topsy-turvy; where the trees grow with their branches downwards, and where it rains, hails, and snows upwards?" Do we not know that Columbus was told by the Sages, that were he to succeed in sailing down the rotundity of the earth its bulging out would prevent him ever sailing up again; and do we not remember with what a stedfast faith in abstract truth he saw beyond "the region of the torrid zone, scorched by a blazing sun, a region of fire, where the very waves which beat upon the shores boiled under the intolerable fervour of the heavens?" Recollect that these were the opinions of a time when the utmost national encouragement was given to intellectual progress, and that it was not very many years after the death of Prince Henry of Portugal, who gave that glorious motto to princes, "the talent to do good." Recollect that this ignorance was manifested in the brightest time of the reign of the enlightened Isabella of Castile, and you will be surprised with me that science has since that time achieved what it has. Had Columbus not investigated the abstract truths of cosmography, the western continent, even with the advantage of the "astrolabe," discovered in his time, would perhaps for a century have re-

mained unknown. It is easy to make an egg stand on its end when the way is shown how to do it. The applications of science are not difficult, but without the science there are no applications. The philosophy of our times does not expend itself in furious discussions on mere scholastic trivialities, or unmeaning questions in theology. The scholastic learning of the middle ages was much confined to ecclesiastics, and it is not surprising to find both classical and theological literature engrafting itself upon the science of the time, and forcing it into the discussion of questions very foreign to its nature. It was a curious mixture of theology and science when the most learned men agitated themselves on subjects such as—the manner in which angels are nourished?—whether they usually speak Hebrew or Greek?—what are the spirits entrusted with the distribution of lightning and hail, and to which are confided the digestive powers of animals?—whether Adam, before the Fall, was acquainted with the *Liber Sententiarum* of Petrus Lombardus? The polemics of a past age do not represent the search after abstract truth of the present. Yet you are in no position even now to treat with derision the past errors of philosophy. The man who is on the mountain complains of the fog obstructing his view, while the inhabitant of the plain speaks of it as a cloud capping the mountain. Both are right, but read the phenomenon differently from each other. Yet only he that was in the fog could rightly appreciate its darkness, or fully understand the force of the rising sun that dissipated its obscurity. The progress of knowledge,—the search after truth,—can scarcely be recognized in its sublimity by those who do not understand the errors which had to be swept away before it could advance in an uninterrupted path.

There are very few instances in the history of science of a sudden development of great discoveries, either illumined from darkness by a flood of light from genius, or betrayed through some accidental and straggling ray. The growth of scientific discovery is slow; it does not, like the prophet's gourd, spring into full development in a single night. The great discoveries of science leave behind them no boundary line of demarcation from those which have preceded, but, like the full day succeeding

the dawning of the sun, follow that which fully foretold their approach. The telescope and microscope did not open their wonders to an unexpecting and startled world, but crept into existence with steps so slow that their impression is not sufficient to trace out the history of their progress. The improvements in the steam-engine were so gradual that a court of law, only half a century since, gave a solemn judgment that Watt had done nothing essential towards them. The compass cannot point to us the period when it offered its inestimable services to man, nor has paper left a record of its discoverer. In fact, all great practical discoveries are the result of much study, the exponent of a long series of observations, and often arise out of those truths of science which appeared least promising on their first announcement. Boyle knew that he wrote an imperishable truth when he titled his Essay "Man's great ignorance of the uses of Natural Things; or, that there is no one thing in Nature whereof the uses to Human Life are yet thoroughly understood." This truth of the seventeenth century is no less true in the nineteenth, the history of the intermediate time having been, as Sir John Herschel justly remarks, but one commentary on the text. The everyday progress of the arts abounds in new applications of objects the most familiar.

Practical, like abstract science, has no limits. The Romans thought themselves at the culminating point of civilization; and the Greeks, pluming themselves in their inventiveness, could not conceive that the world would ever take a higher flight. Even in our times, like opinions are entertained; because ignorance cannot see over the heights raised by modern science for a wider view of creation. These conceited ideas of a nation or of an age have no foundation. Science may see an horizon bounding her view; but as she proceeds onward the horizon constantly recedes, and shows the limit to be altogether illusory. In one time and generation a nation may, like Newton, pick up a few pebbles on the seashore, while the boundless ocean of science lies beyond, with all its vast and unexplored treasures.

Empiricism has frequently been a substitute for science; a lame and sluggish substitute, it is true, but nevertheless one

that in the history of mind has had much of influence. Gunpowder was known before the condensed air of which it consists was recognized or understood; and it succeeded in killing man, without a knowledge that man himself is little more than air similarly condensed. Man used and succeeded in producing condensed air in the form of food, without having the slightest conception of the character of the air out of which this wondrous transformation was effected. Without a knowledge of atmospheric pressure, mills and pumps were formed. Glass was produced from the ashes of the fern, and china from kaolin, without a knowledge of the principles involved in their production. The length of the year was known, and the duration of the seasons explained, without the law of gravitation being suspected. All this, it is true, arose without science, but required ages to grow into a stunted and feeble childhood; while no sooner did science remove the trammels of ignorance, than a few short years produced a vigorous manhood. Ignorance may grope in darkness on the confines of an unexplored region, but to proceed steadily and securely onwards she must borrow the lamp of science to guide her. Newton, "that glory to his species," as Chalmers calls him, did, by the exposition of the law of gravitation, produce more real practical benefits to industry than all the preceding ages of empiricism. Navigation and Commerce sprang from his time into a state of development formerly impossible; and every nation and every human being enjoys from him, and to the end of time will enjoy, actual material benefits which an eternity of empiricism could not have produced. The hard-won experience of two thousand years of the Chinese in regard to porcelain was given to the European by a few years applications of science. The improvements in postal communication, which allowed our kings to transmit a message to Edinburgh in five days, now enable us to send it in less time than their "post-haste messenger" could saddle his horse. But these, and other triumphs of mind over mere empirical experience, arose from a steady progress of abstract science, the practical applications appearing merely as offshoots. It is my chief object to show that abstract science is necessary to the development of

practice, and that it is above all things necessary to make it a part of the education of a man who is to devote his life to the progress of industry. There is no vein of science too abstract for future industrial application; none yet thoroughly mined out and exhausted. Volumes might be filled with illustrations of the practical benefits produced by the application of discoveries apparently the most unpromising in their origin; but a few only can be selected in support of the text of my argument.

The most "practical" man,—a title erroneously used by our English to envelope their ignorance,—could not have objected to the marvellous development of truth arising from the study of light, that messenger from the sun sent at the rate of 180,000 miles in a second, to illumine our earth with the glory of its parent. It was wondrous to be told that the light of yonder far-distant fixed star, travelling without cessation at the same incredible speed, and which has this night struck our wondering eyes, started in its long and weary course some billions of years since, and has now for the first time shed its pale light on such points in time and space as ourselves. The sublimity of these truths awes the utilitarian, and hushes his half-uttered question of *cui bono?* But show him a young officer of artillery looking through a prism at the windows of the palace of the Luxembourg, and noticing that, in a particular position, the light of these windows disappeared from his view—show him, further, the startled wonder with which the philosophers of Europe heard of this phenomenon, and the eagerness with which they threw themselves into the track of an observation apparently so insignificant,—and your utilitarian sneers at science and its followers, and buries himself again in the darkness of his empiricism. The light reflected from the palace of the Luxembourg had suffered a change similar to that experienced by ordinary light in passing through doubly refracting Iceland spar. When a ray of this changed or *polarized* light is passed through plates of crystallized substances, brilliant colours and a peculiar structure are observed. These remarkable phenomena were indeed well worthy of the attention of scientific observers. Nothing, however, could

appear more remote from practice than the study of an altered beam of light. It was most interesting that, as in the case of sound, where two sounds reaching the ear either exalt or destroy the effect, so, in light, two rays interfering with each other may produce darkness. Much of the light from reflecting surfaces was found to possess this changed condition. The light coming from the surface of water being thus altered, refuses to pass through a "Nicolls' prism" in a particular direction. If, therefore, you look at the shadow of a man on a smooth lake, on turning round the prism the shadow disappears, while the man, seen by common light, remains visible. The story of Peter Schlimmel is thus realised. But who, from these curious observations, would have dreamt that out of them would come useful applications?

In a short time, however, this property of the polarizing prism was applied to the important purpose of detecting rocks and shoals at sea. It had long been the practice of mariners, when they suspected the existence of shoals, to look out for them at the masthead, because the outlook from his vertical position shut out much of the light that dazzled and obstructed his view. But as part of this dazzling reflected light is polarized, it is obvious that the polarizing prism enables the observer to scan the depths of the ocean, uninterrupted by its glare. Behold then the light which struck the student's eye when gazing on the Luxembourg used to preserve man from the hazards of the sea. It was easy to apply it in new directions; and the salmon-fisher speared fish at depths inaccessible to his unaided vision; while the engineer used its searching powers to discover the laws of tension in beams. Mechanics and Chemistry both pressed it to further their resources. Under the hands of a Biot, a ray of polarized light performed with magical quickness the most refined but tedious operations of the analytical chemist, and enabled him to tell the amount of sugar in the cane or beet juice. He thus followed the increasing richness of sugar in the juices of various plants at different stages of their growth, and was enabled to suggest a more economical adaptation of the labour applied to their cultivation. Thus, when beet is ready to be gathered, labour is in demand for the harvesting of other

crops, and consequently is expensive. It would not then do to take another crop, such as parsnips, inferior in its amount of sugar, as the cost of production would outweigh the return; but when the horses and carts are disengaged, and labour is cheap, parsnips are richest in their amount of sugar, and the idle mills may be usefully employed in producing sugar from this plant. By the same ray of light the size of distant objects may be measured, and even time may record its passage. This latter application, made by Wheatstone, is especially remarkable, and gives a means more accurate and useful than the sun-dial of determining the apparent solar time by the diurnal changes of the plane of polarization at the north pole of the sky. By availing himself of the fact, that the planes of polarization in the north pole of the sky change exactly as the position of the hour circle alters, he has adapted a simple and ingenious apparatus, by which the true time may be told within three minutes. All these are strange paths to practice, opened out by a ray accidentally caught in its passage from a window of the Luxembourg. Pass from its utilitarianism to its unfolding of nature's laws, and follow the same straggling ray, as it silently displays its gorgeous colours while passing through a transparent mineral substance, until it gives to man the knowledge as to whether the light of the sun proceeds from its solid mass or from its gaseous canopy, or whether comets enjoy light of their own, or borrow it by reflection from other bodies.

I now pass to light in its ordinary form, and ask you to examine the importance of studying its abstract phenomena. The world had long known that salts of silver were blackened by exposure to light; and the fact became familiar by their use as cauteries, or as indelible inks for linen, Wedgwood proposed to apply this means to fix the fleeting pictures of the camera obscura; but the results of his experiments being imperfect, the suggestion itself was almost forgotten. In the meantime chemists pursued their abstract discoveries, and without relation to this want investigated the properties of gallic acid, and of the iodide of bromine, and found a class of salts termed the hyposulphites. Some of these bodies pos-

sessed properties accelerating the blackening of silver salts by light; the others prevent the further blackening when applied. Philosophers began now to revert to the old idea, for truth is never lost, though its reality may be incapable of proof at a given time; and thus various unconnected discoveries began to re-act one upon the other, until man was able to use the Sun as the painter of the pictures exhibited and enlivened by his glory. So perfect became the art, by new adaptations of other discoveries, that the most fleeting objects can be depicted. The flash of lightning exhibits its fiery streak on these sun-painted pictures. The tossing out of lavas, the vomiting forth of smoke, and the bellowing of flame from craters in their wildest moods, are pourtrayed with unerring fidelity; the tumultuous dashing of the cataract and the slight rippling of the stream, the changing forms of the clouds, the sparkling of the rain-drop, and the ever-varying expresssion of the human countenance, are all capable of being preserved in these paintings by nature. Nay the truthfulness of the sun-painted landscape is so great that from the very shadows of the picture the altitude of the sun may be determined; and the time at which it was taken being known, the latitude of the locality may be elicited. Artists now use this application of light to acquire models for study; and the engineer employs it to obtain proofs of the exact state and progress of the works superintended by him. Doubtless very soon, for it is now all but accomplished, the Sun will be compelled to fix those transitory coloured glories which he now imparts to natural objects; but not till then should man cease to question him as to the means of accomplishing this end. I need not say that this art is but disclosing its future applications. Already can we use the sun to record observations too delicate for man's perception. The constant and momentary excursions of the magnet, the ever-recurring variations of the thermometer and barometer, are now recorded by light with a fidelity and precision unattainable by the most conscientious and unremitting observers.

These instances will suffice to show that the study of abstract laws, so far as regards light, produces as offshoots important practical applications; and in each department of science, like

lessons may be taught. There never was an age so rich in practical applications as that in which we live, and it is interesting to see them drawn from truths long familiar to man, and apparently beyond the range of utilitarian application. When an Italian physician, having hung on an iron railing the legs of a frog fastened to copper hooks, observed that each gust of wind caused convulsions in the legs of the dead animal, who could have prophesied that this observation would entirely alter the character of a future century? and yet it is but an application of this discovery, extended, it is true, by many intermediate researches, that annihilates space and time,—that empowers our thought to travel with the speed and with the power of lightning to the most distant land, and enables mind to be reciprocated without being arrested by distance in space. Who could have dreamt that the same discovery of Galvani would in future join continents, in spite of intervening seas, and give more security to nations than cordons of soldiers or fleets at sea, by rendering sudden invasion all but impossible? At the late Exhibition you had a singular proof of this quick interchange of intelligence, for every morning you could buy at a trifling cost a map showing the state of the wind, of the barometer and thermometer, in all the principal towns in Great Britain during the previous day. You have already seen how useful may be made this discovery; for a transit of a star at Greenwich and at Paris may be instantaneously recorded, and their respective longitudes verified. As a means of communicating intelligence, its powers are not yet nearly developed; for in its mercantile communications it produces consequences no less individually important than its general results, such as when it sends information to distant provinces of the approach of a tornado, time being thus given to provide against the fury of the storm. It is rare indeed that brilliant discoveries, such as the electric telegraph,* flash matured across a human intellect, and in a generation produce such mighty results. It is true

* The electric telegraph, as now used, is a *discovery* in science, and not a mere application or *invention;* for it was a most important discovery that the earth itself could be used as part of the circuit.

that some of the most wonderful discoveries have been shadowed forth by a sudden inspiration; but in few cases has that shadow appeared as a picture with all its lights and shades. Before steam had been subjugated to the service of man, in accelerating his transit on land or water, Darwin had said,

> " Soon shall thine arm, unconquered steam, afar
> Drag the slow barge, or move the rapid car."

By a similar prophetic spirit, resulting, however, partly from induction, Goethe saw that the parts of flowers are metamorphosed leaves, and Oken, when stumbling over a bleached skull, perceived that the osseous system was constructed on the vertebral type. But it was only by patient and long-continued study that these thoughts became substantive realities. This is essentially the case in electricity, which is but now beginning to reward mankind at large for all the patient investigations of the philosopher. Already has the fierce and untamed lightning allowed itself to be dragged from its course, and be conducted tranquilly to places where its fury is dissipated without injury to man. Even in its fiery flashings in the wide expanse of the ocean, it submits to the intellect of a Franklin, and leaves unscathed the ship rolling on the stormy waves. Providence, in His beneficence to man, has allowed him to find " a way for the lightning of thunder." Artificially formed, it allows itself to be conducted through land and sea, humbly serving the purposes of man, by blowing up mines, or enabling him to rescue treasures from sunken vessels.

This immaterial power produces material results at places fixed on by the will of man; and London may now fire a friendly salute at the Invalides, while Paris returns the compliment with the guns of the Tower. Although, as yet, electricity is not used with economy as a motive power, the obstacle is only in the cost; and even this may be resolved as discoveries progress.

Although her passage is so rapid that a journey to Paris can scarcely be expressed in time, yet she may be controlled, and used to record time's own progress; for nothing is more accurate than clocks worked by her power. It would not be difficult

to have all the clocks in a town worked with perfect uniformity by the aid of electricity.

Electricity now plates with gold and silver the baser metals; copies in metal from more perishable materials the most exquisite designs and forms; perpetuates the skill of the engraver, by multiplying, at a trifling cost, his elaborately engraved plates; and separates and purifies the metals, formerly only obtainable by tedious and complex chemical operations.

Electricity offers for your lighthouses light of a brilliancy the most intense, and asks you to substitute the light gas which streams through the streets by a still more ethereal existence, running along simple wires.

Even in the smallest offices of good-will to man she refuses not her aid, and offers to tell the perfumer whether his essential oils are adulterated with cheaper fatty substances, as willingly as she lends aid to the Chemist in the minute operations of his laboratory practice, or as she kindly ministers with the Physician to allay human suffering and restore wasted strength. Recollect, that all these are but the beginning of her applications, and that we know not to what extent they may be carried out; and rejoice with me that philosophers studied her abstract laws, from the knowledge of which these applications have arisen.

I have no time to extract further examples from physics or meteorology, but I cannot refrain from directing a passing glance at the beautiful discoveries of Colonel Sir William Reid. Studying the phenomena of a hurricane at Barbadoes, he followed out his observations to all recorded hurricanes, and thus elicited the simple law that hurricanes and many gales are progressive whirlwinds, revolving in the direction of the hands of a watch in the southern, and in the reverse direction in the northern hemisphere, but moving along in its mass at the same time. The variable winds in a hurricane now become intelligible, and a mariner caught by it may use every wind to steer out of its course, and prevent himself being overwhelmed in its vortex. To be wrecked in a hurricane, with an open sea, can now only result from a lamentable ignorance of scientific laws; for knowledge has triumphed over the terrors of the storm.

Let us now turn to Chemistry proper, and see how this supports the text of the argument. It is an old science, and from the time of Tubal Cain to that of Liebig has been progressing steadily onwards, though not always with similar aims and aspirations. The alchemists erred, as England now errs, by valuing and studying only practical applications, instead of following abstract laws. Health, wealth, and longevity comprised their aspirations, in the place of eternal truth. But these objects were sufficiently important to produce in their search "a zeal allied to madness," and facts became accumulated of infinite importance to the science when it attained self-consciousness, and learned to value itself for its nobler ends.

No later than the time of Henry IV., a royal edict recommended that "the clergy should search for the philosopher's stone, for since they can change bread and wine into the body and blood of Christ, they must also, by the help of God, succeed in transmuting the baser metals into gold."

As soon as Chemistry began to be studied for the mere sake of abstract truth, then she deigned to reward man for his unselfishness by numerous collateral results having a direct material benefit.

He who supposes that Chemistry is the result of practical knowledge derived in its contact with industry knows little of the progress of the human mind, or is little grateful for the infinite development which it has given to human resources and human enjoyment. Let us select a few examples of abstract chemical truths bearing on practical appliances. I will first refer to the Miners Safety Lamp as a most important example of an industrial result depending upon pure induction from abstract science. An element of destruction, apparently uncontrollable by human power, had to be subjugated so completely as to be put under the management of the most uneducated miner. More dreadful in its effects than those of the lightning and the earthquake, fire damp, the scourge of the miner, seemed to defy investigation even as a scientific phenomenon. By a pure inductive method, such as a Bacon would have loved to witness, Davy traced its history, step by step, until he fully made out all its characters. He discovered that it in reality requires a very high heat for ignition, the temperature of red-

hot iron or charcoal being insufficient to inflame it. The gas was found not to explode in narrow tubes, as these cool it below the point of ignition; and a network of iron wire is only a series of sectional tubes. A lamp surrounded by wire gauze is now constructed, and this allows a light to be carried into the most dangerous mine with perfect safety. What a wonderful discovery is this! The destructive gnome of the mine is imprisoned within a cage of mere wire gauze, and, vainly struggling to escape, heats to redness the bars of its prison. Science, to its glory, has destroyed those scenes of death and heart-sickening misery which haunted the miner in his most peaceful hours, and has rendered safe an occupation formerly one of dread and danger.

When Dumas investigated the laws of substitution, and discovered a new body by distilling alcohol with bleaching powder, interesting indeed in its chemical formula, but capable of being sneered at by those who see science at a distance, by a wrong-end telescopic view of its commercial productiveness; who could have dreamt that this *chloroform* was destined to remove many of the woes which man is heir to, by mitigating pain, and preventing its occurrence even in the most severe surgical operations?

In 1842, I had the pleasure of travelling with the Dean of Westminster and Liebig over different parts of England. Among other places we visited a limestone in the neighbourhood of Clifton, where in former times saurian reptiles had been the pirates of the sea. There, along with the relics of the fishes on which they had preyed, were their own animal remains. Coprolites existed in great abundance, and proved the extraordinary number of the reptiles which must have existed. The interesting question arose as to whether these excretions of extinct animals contained the mineral ingredients of so much value in animal manure. The question was in fact not yet solved by the chemist, and we took specimens, in order to confirm by chemical analysis the views of the geologist. After Liebig had completed their analysis, he saw that they might be made applicable to practical purposes. "What a curious and interesting subject for contemplation! In the remains of an extinct *animal* world England is to find the means of increasing her wealth in agri-

cultural produce, as she has already found the great support of her manufacturing industry in fossil fuel—the preserved matter of primeval forests—the remains of a vegetable world! May this expectation be realised! and may her excellent population be thus redeemed from poverty and misery!" I well recollect the storm of ridicule raised by these expressions of the German philosopher, and yet truth has triumphed over scepticism, and thousands of tons of similar animal remains are now used in promoting the fertility of our fields. The geological observer, in his search after evidences of ancient life, aided by the chemist, excavated extinct remains which produced new life to future generations.

Two years before this, the same German philosopher, in his researches into the food of plants, had drawn attention to the importance of guano as a manure, and by his intellect wafted fleets to the Ichaboes and to the Incas.

Man gets so accustomed to luxurious applications of science, that he often forgets the searcher of abstract truth whose discoveries led to them. Nothing is more useful than has been the discovery of the lucifer match. Some of us recollect the time when the tinder-box was the only artificial means of procuring light, and a lively remembrance of the often-unsuccessful efforts, always tedious and lengthy, is required fully to appreciate the value of the lucifer match. What an improvement it was when a little bottle of oil of vitriol could be carried about, and by dipping matches into this, light was obtained! And yet this elegant method is now considered clumsy, and is entirely superseded in less than ten years. The properties of chlorate of potash and of phosphorus became by study better understood, and their application to the production of artificial light was apparently perfected. But the lucifer match maker is dangerous to society, and a curse to himself. The transparent waxy phosphorus with which he works must always be kept under water, and even then is so hazardous that insurance offices decline to insure the premises in which it is contained. The heat of the hand causes it to inflame, and the worker, even avoiding this, becomes diseased and liable to ulcers. The practical man now helplessly lays his wants

before the searcher of abstract truth. Chemists had for some time noticed that various bodies assume different forms, as, for example, carbon, in the states of diamond, graphite, and charcoal. An Austrian chemist, Professor Schrötter, investigating the abstract laws of allatropism, inquires whether phosphorus has more than one form, and by heat changes the transparent wax into a scarlet body. This scarlet substance is the same phosphorus, but in a state in which it may be kept in the open air, or packed up and transported in casks, and is not readily inflamed by a gentle heat or by friction. Physiologically it has little action on the body, and yet by proper admixtures makes as good lucifer matches as the ordinary dangerous phosphorus. By these discoveries the means of giving artificial light is rendered a safe and healthy manufacture.

A French chemist discovers that paper immersed in nitric acid unites with that body, and becomes highly combustible. Any woody fibre is subsequently found to do the same. This observation lies dormant for years, noticed only as an interesting fact, under a long and scientific term, in the books of chemists. But one day a Swiss chemist announces the startling fact, that the peaceful cotton bales of Manchester may be converted into dangerous ammunition of war, and that cotton unchanged in its physical appearance has been made more destructive than gunpowder. There was something appalling in the fact of this peaceful representative of industry being made to assume such destructive properties, under the magic wand of the chemist. The chemist now examines cotton in the new form, and trying to purify it, finds that it is soluble in ether. When left exposed, the ether quickly evaporates, and the gun-cotton retains a skin-like appearance. Surgeons seize the discovery of the chemist, and gun-cotton dissolved can heal the wounds it makes in its dry state. Numerous applications follow, and man, forgetting his fear, uses the gun-cotton to silver mirrors, and to produce the portraits of his friends on glass, by a process speedy as the Daguerreotype. Another chemist, seeing how readily cotton unites with acids, investigates its power of combining with alkalies. He discovers that it does so, but notices that a contraction ensues in its fibres. Looms are not now required to

make coarse calico fine, for immersion in soda makes it take the form of fine cambric. The alkaline calico washed in water loses its soda, but unites with water, and this in turn is displaced by colours when the calico is dyed, so that the calico assumes dyes of much greater intensity and brilliancy.

Analogous to this is the application of a well-known fact to the manufacture of flax cotton. As long ago as the time of Solomon, it was well known that acids produce an effervescence with carbonate of soda, for that wise King says, singing songs to a heavy heart is like pouring vinegar upon natron (mistranslated nitre). This old fact is now used to separate the fibres of flax, and give to it a cotton-looking appearance and properties. But this would have been insufficient as a practical result, had it not been that scientific discoveries had shown the existence of a class of bleaching compounds, termed hypochlorites, which enable a few hours to do the work of many weeks.

These various discoveries of Schonbein, Mercer, and others, did not in any case arise from a direct practical search, but as offshoots of abstract investigation.

Antioch, in the beginning of the fourth century, discovered the importance, as a matter of police, of lighting its streets. But the discovery lapsed, and it was only in the middle of the sixteenth century that Paris lighted up her streets by fires made of pitch and rosin. Slowly did this matter of primary police creep on till the end of the last century, when it started forward with extraordinary vigour. Chemists had long observed that coal on being distilled produced a combustible gas, and the means of collecting and distributing various kinds of gas were among the common experiments of a lecture table. But it was not till 1792 that Murdoch employed coal gas to light up his offices at Redruth. Now gas has entirely substituted oil in the lighting of streets, but simply as a question of cost, the coals from which it is produced being cheaper than the corn necessary to form tallow. It by no means follows that gas is always the most convenient form of using a combustible. "It would certainly," says Liebig, "be considered one of the greatest discoveries of the age if any one could succeed in condensing coal gas into a white, dry, solid, odourless substance, portable, and capable of being placed upon a candlestick or burned in a lamp." A want

is rarely clearly expressed by man that science does not administer to it; and already is the desire of Liebig accomplished. A mineral oil flowed out of coal in Derbyshire, and was obviously produced by a slow process of distillation from the coal. It contained solid paraffine dissolved in a liquid oil. Mr. Young, of Manchester, in examining the mode of its formation, found that paraffine, a solid waxy substance hitherto never produced from coal, could in reality be readily formed in commercial quantities by a slow and regular distillation. This, in fact, is "condensed coal gas," or, rather, it might be considered as a solid form of olefiant gas. It is therefore really the want of Liebig supplied. In forming coke, this product, dissolved in an oil of a similar composition, may readily be obtained; and useful products are made instead of those waste gases now thrown uselessly into the atmosphere. It might appear chimerical to you if I were to state many of the consequences which must follow if this discovery in its maturity be found as successful as it promises to be in its dawn; but it is not difficult to see that a cheaper and less carbonised coke could be burned in our domestic fires; and thus we might see a sun which now refuses to penetrate the sooty canopy of our cities.

Hour after hour might be employed in recording the triumphs of chemistry in its investigations into the play of the organic elements. Looking back no further than the last few years, you see how it has thrown open the most hidden processes of animal and vegetable life; how it has taught us to increase and economise the food of man. It is even yet the practice of those who have not followed her discoveries into the wondrous affinities of the few simple organic elements to depreciate the importance of following their infinite creations. If, however, there were no other result from doing so than the one great achievement of having explained the ingredients in food used to build up the muscular frame and those employed in the support of animal heat, the importance of that discovery would have repaid all the labour of the past century.

Almost all the staple manufactures of this country are founded on chemical principles, a knowledge of which is absolutely indispensable for their economical application. In a few educational establishments and in some of our universities the alphabet

of chemical science is taught; but it requires an institution such as this, devoted to a special object, to teach how to use that alphabet in reading manufactures. The extension of scientific and technical education is a want of the age. The old and yet widely-existing scholastic system of education introduced by the revival of learning in the fourteenth and fifteenth centuries is ill adapted to the necessities of the times. Erasmus would not now aid Cambridge in advancing the progress of England, nor would Vitelli make Oxford useful to the mass of its population. It would be of little use to the lagging progress of Italy even if Chrysoloras were again to teach Greek in its universities. Euripides and Thucydides cannot make power looms and spinning-jennies; for these Watts and Arkwrights are required. A Poggio may discover copies of Lucretius and Quintilian, without thereby producing a result equal to that of the smallest inventions of a Stephenson or a Wheatstone. When will our schools learn that dead literature cannot be the parent of living science or of active industry? I do not underrate classical learning as an elegant accomplishment, or as a branch of human knowledge; I can rejoice as much in a good thought from Plato, or a happy allusion from Aristophanes, as I can in hearing a discussion on the philological affinities of the Indo-Germanic tongues; but I cannot understand why our sons of industry, destined to reap its harvests, should be placed in its fields of corn, having only been taught how to cull the poppies. "The great desideratum of the present age," says Liebig, "is practically manifested in the establishment of schools in which the natural sciences occupy the most prominent places in the course of instruction. From these schools a more vigorous generation will come forth, powerful in understanding, qualified to appreciate and to accomplish all that is truly great, and to bring forth fruits of universal usefulness. Through them the resources, the wealth, and the strength of empires will be incalculably increased."

Institutions, such as this, are not substitutes for, but supplements to, the universities. It is the industrial training which we profess, and everything else is made subsidiary to that object. Not that we do or should forget abstract science, as such, because I believe the discoveries in abstract laws are of more

real benefit to industry than their immediate applications. The technical man is, perhaps, of more use to himself and to his time and generation than he who discovers the abstract laws applied by the former to the purposes of industry; but it is the abstract philosopher who benefits all time, and confers universal and eternal benefit to society.

If I have convinced you that it is of infinite importance to a nation, not only to study science as constituting the foundation on which industry rests, but to promote the advancement of abstract science, the soul and life of industry, you will readily understand the importance of institutions the object of which is to infuse this life into special departments of technology. England has too long rested on the position which it has acquired as a manufacturing nation. This position was gained when local advantages gave an impulse to our practical national mind. But now that the progress of human events has converted the competition of industry into a competition of intellect, it will no longer do to plume and pride ourselves on our power of mere practical adaptations. It is miserable to see our industrial population glorying in their ignorance of the principles on which their manufactures depend, and vaunting their empiricism, or, as they term it, their "practice." Let us waken from this delusion, unless we prefer to—

> "Sit like spent and patient fools,
> Still puffing in the dark at one poor coal,
> Held on by hope till the last spark is out."

If England keep pace with other countries as a manufacturing nation, it must be by her sons of industry becoming humble disciples of science. At present her reliance in the "practical" or "common sense" of her population is the sunken rock directly in the course both of her agriculture and manufactures. On this subject Archbishop Whately has some excellent remarks. "By common sense," says he, "is meant, I apprehend (when the term is used with any distinct meaning), an exercise of judgment, unaided by any art or system of rules; such an exercise as we must necessarily employ in numberless cases of daily occurrence, in which, having no established principles to guide us, no line of procedure, as it were, distinctly chalked out, we must needs act on the best extemporaneous

conjectures we can form. He who is eminently successful in doing this is said to possess a superior degree of common sense. But that common sense is only our *second best* guide,—that the rules of art, if judiciously framed, are always desirable when they can be had,—is an assertion for which I may appeal to the testimony of mankind in general, which is so much the more valuable, inasmuch as it may be accounted the testimony of *adversaries;* for the generality have a strong predilection in favour of common sense, except in those points in which they respectively possess the knowledge of a system of rules, but in these points they deride any one who trusts to unaided common sense. A sailor, e. g., will perhaps despise the pretensions of medical men, and prefer treating a disease by common sense; but he would ridicule the proposal of navigating a ship by common sense, without regard to the maxims of nautical art. A physician again will perhaps contemn systems of political economy, of logic, or metaphysics, and insist on the superior wisdom of trusting to common sense on such matters; but he would never approve of trusting to common sense in the treatment of diseases. Neither, again, would the architect recommend a reliance on common sense alone in building, nor the musician in music, to the neglect of those systems of rules, which, in their respective arts, have been deduced from scientific reasoning, aided by experience; and the induction might be extended to every department of practice. Since, therefore, each gives the preference to unassisted common sense only in those cases where he himself has nothing else to trust to, and invariably resorts to the rules of art wherever he possesses the knowledge of them, it is plain that mankind bear their testimony, though unconsciously, and often unwillingly, to the preference of systematic knowledge to conjectural judgments." Practice and science must now join together in a solemn union, or the former will soon emigrate to other lands. The time is past when practice can go on in the blind and vain confidence of a shallow empiricism, severed from science "like a tree from its roots." The rudest sailor may steer his ship in the direction of a landmark, but without compass and sextant he dare not traverse the expanse of ocean. Ignorance may walk in the path dimly lighted by advancing knowledge, but she

stands in dismay when science passes her; and she is unable to follow, like the foolish virgin having no oil in her lamp. Depend upon it, an empirical knowledge of practice is not the way now to succeed in the struggle of individuals, or in the struggle of nations. Intellect is on the stretch to get forward, and that nation which holds not by it will soon be left behind. For a long time, practice, standing still in the pride of empiricism, and in the ungrateful forgetfulness of what science has done in its development, reared upon its portal the old and vulgar adage, "an ounce of practice is worth a ton of theory." This wretched inscription acted like a Gorgon's head, and turned to stone the aspirations of science. Believe it not! for a grain of theory, if that be an expression for science, will, when planted, like the mustard seed of Scripture, grow and wax into the greatest of trees. The pressure and difficulties of the age, and the rapid advancement of intellect in continental nations, have been the Perseus to cut off this Medusa's head from the industry of England, and to fix it on the shield of Minerva, who turns to stone such as still believe that science should be ignored by practice; but, reversing that shield, wisely conducts those who would go further under her guidance. It is now rare to find men who openly avow, although they actually entertain, a belief in a necessary antagonism between theory and practice. Theory is in fact the rule, and practice its example. Theory is but the attempt to furnish an intelligent explanation of what is empirically ascertained to be true, and is always useful, even when wrong. Theories are the leaves of the tree of science, drawing nutriment to the parent stem while they last, and by their fall and decay affording the materials for the new leaves which are to succeed.

I have now said enough to show you that it is indispensable for this country to have a scientific education in connexion with manufactures, if we wish to outstrip the intellectual competition which now, happily for the world, prevails in all departments of industry. As surely as darkness follows the setting of the sun, so surely will England recede as a manufacturing nation, unless her industrial population become much more conversant with science than they now are.

The Relations of Natural History to Geology and the Arts. (*A Lecture Introductory to the Course to be delivered during the Session* 1851–1852.)

By Edward Forbes, F.R.S.

Natural History is a vast and continually extending science. It embraces Zoology, Botany, and much of Geology. The sections of it are subdivided into studies, each of which, if pursued to its full development, would more than occupy a life-time. No single man can, in the present state of knowledge, grasp the details of all the natural history sciences, or even of one of their great sections. But the principles that pervade all are the same. The same laws govern the animal and vegetable kingdoms. The same laws regulated the phenomena of animal and vegetable life through the geological past that now regulate them in the historical present. That such is true is for the naturalist to demonstrate. The zoologist, the botanist, and the geologist contribute the elements of the demonstration, but the great pervading principles of the entire science demand a combined study of the three kingdoms of nature. The task assigned to me in this Institution is the exposition of these principles; their illustration by examples drawn from existing and extinct forms of life; and the teaching of such details of zoology and botany, recent and fossil, as are necessary to the accurate conduct of geological research, and have thereby a practical and economic bearing, through the certainty they give to geological determinations. A second and distinct duty, hereafter to be performed, will be the illustration of the application of natural history knowledge to the arts and manufactures.

Of all the departments of the educational system adopted in this Institution, mine is apparently the least practical. The chemist, the metallurgist, the mechanician, come directly into contact with the arts and their votaries. The miner furnishes the materials from which so much of the riches of England is derived. The geologist investigates the structure of the country, and thus gives certainty to the operations of the engineer, developes new sources of mineral and agricultural wealth, and prevents the expenditure of capital in wrong directions. All men understand why the manufacturer and artizan are indebted to the chemist and metallurgist, whose obligations to the miner and the geologist are too evident not to be freely acknowledged by themselves and those who benefit by their pursuits. But the naturalist seems to work apart from practical men. His duties are performed behind the scenes, and make no conspicuous show. His share in the work can be fully appreciated only by the geologist, whose requirements necessarily lead him into the palæontological laboratories. Like a labourer among the foundations of an edifice, he is unseen by the crowd who admire the beautiful superstructure, though without his labour the building would be unsafe and incomplete. It needs but a brief argument to prove this to an intelligent audience.

That geology is an essential element of a scientific mining education is obvious at first thought. That natural history should be, may not seem so evident to persons as yet unversed in geology. That palæontology is an essential element of geological science, no one who is acquainted with the rules by which the relative ages of sedimentary rocks are determined will deny. And that palæontology, apart from natural history, is empirical and false, and has no claims to the dignified title of science, every intelligent student of organic remains will maintain. Therefore, the teaching of the study of fossils in this Institution is to be conducted with constant reference to and comparison with living organisms; for by no other method can we hope to gain an insight into the history of the manifestations of life during the geological past, such as is necessary for the truly scientific, and, consequently, *safely practical* study of geological science and its applications.

The value of natural history as an educational science has been but partially recognized in Britain. In our schools and colleges, the chief cultivation has been directed to the nurture and training of the memory, the reasoning powers, and taste; not always by the most judicious methods. Observation, a faculty upon the correct exercise of which the value of the others in a great measure must depend, has been neglected or even entirely ignored. Yet to observe truly, to note accurately, are surely qualities of essential importance to the well-being and future prospects of every youth. The successful progress of a man through life, the weight attached to his statements, must, in a great measure, depend upon them. The simplest, easiest, and most beneficial method of cultivating the observing powers lies in the acquirement of the methods and practice of the natural history sciences. Ignorance alone could have excluded them from recognized courses of education. Though partly taught in some of our Universities, it is as branches of knowledge usually in connexion with the enlightened profession of medicine, and not on account of their value in educational training. Of late, however, there has been a tendency to rectify this. Oxford and Cambridge have recognized, in theory at least, the right of natural history to share in their honours. Their younger sister, London, with the timidity of youth, has hesitated to pronounce in its favour. In the metropolitan colleges, and the universities of Scotland and Ireland, the natural history sciences are taught by able professors; but the total number of their unprofessional disciples is small, and cannot be said to be increasing. In schools of lesser grade they assume, when professed to be taught at all, the form of intellectual recreations; not that of exercises, and strengtheners of the mind of the pupil. The time, I trust, will yet come when every student will be required to educate his observing powers through the agency of these delightful branches of study.

The earliest efforts of infant intellect are directed towards the observation of natural objects. Animals, plants, minerals, are collected by the schoolboy, who delights to note their shape and qualities, and rudely to compare and classify. But the thirst for natural knowledge thus early and unmistakeably manifested

is rudely quenched by unpalatable draughts of scholastic lore, administered too often by a tasteless pedagogue, who, blind to the indications of a true course of education, thus plainly pointed out by human nature, developing itself according to the laws of its own God-given constitution, prunes and trims, binds and cramps the youthful intellect into traditional and fantastic shapes; even as the gardeners of a past age tortured shrubs and trees into monstrous outlines, vainly fancying to improve their aspect, arresting the growth of the spreading boughs and the budding of the clustering foliage, mistaking an unhealthy formality for beauty. Far be it from me to disparage the educational value of the glorious literature of Greece and Rome, or to withhold due honour from the many able and learned men who give dignity to their profession as educators. To them I would appeal for the rectifying of the evils of a one-sided education. I would implore them, in the name of Aristotle, the greatest of naturalists, and most admirable of observers—how great otherwise none knows better than they do—to avail themselves of that science upon which he laid so much stress, and through it to cultivate those tracts of the mind of youth that now lie fallow and unproductive.

I speak thus strongly respecting the neglect of the sciences of observation in the ordinary practice of education in England, because it is too probable that in it lies one of the chief difficulties with which schools of applied sciences will have to contend in the outset. The rudiments of science should be taught elsewhere. The student should come prepared with a groundwork of elementary training, which there is too much reason to fear, in the present condition of schools and schoolmasters, he will have great difficulty in obtaining. The training for scientific study should be effected in preparatory schools. The teaching here should consist in the communication of scientific knowledge, and in the elucidation of the applications of it. But we do not despair. The events of this year have gone far to awaken Englishmen to the consciousness of the dignity that is inherent in those pursuits which have made their country so powerful among nations. The union of practice with science is the surest way to keep her strong

position. Through the operation of well-devised educational establishments only can that union be cemented, and future results secured.

In the scheme of education adopted by the School of Mines it will be observed that palæontology is regarded as inseparable from natural history. I have already said that the study of organic remains, conducted independently of the study of living organisms, is essentially empirical and injurious to science. The value, the interest, the scientific and practical importance of fossils, depend entirely on the knowledge of their true nature, which we gain through a comparison of them with their existing homologues and analogues. That comparison cannot be understood unless we make ourselves acquainted with the habits and organization of the living types with which fossils must be compared. There are now nearly 30,000 kinds of fossils known and described; these have been discovered in formations of all epochs. Some of them are the remains of beings that lived at immeasurable distances of time,—some of them are the skeletons of creatures that flourished along with the ancestors of species now existing. Yet all researches hitherto made have gone to show that every form of extinct life was a member of the same great series of beings with those which now inhabit our world,—that the laws of organization and the laws of life were the same in the primeval epochs of Preadamite time as now,—that the same great universal thought has uniquely pervaded the one great creative action,—that the repeated manifestations of creative power during successive ages have ever announced the one consistent idea.

It is not an uncommon fancy to suppose that naturalists are occupied entirely with the naming and describing of the kinds of animals and plants; that, provided they can enumerate in clear though technical language the characteristics or features of a being submitted to their examinations, usually in the state of a preserved specimen, and, on discovery of the species being one hitherto unnoticed, give it a name by which it may be remembered by their brother naturalists to the end of time, or thereabouts, they have attained all their aim, and fulfilled all their ambition. This notion of their duties and offices is a libel.

It takes note of only a fragment of their labours. To name and describe are but to enrol an object, with a true spelling and clear definition, in the great dictionary of science. Words in dictionaries are exhibitions of the raw materials out of which literature is made; and species arranged in zoological and botanical systems are orderly and beautiful displays of the raw materials of natural history science. Words may be wasted, and species misused. But the study of species, which is the basis of all natural history science, does not take note merely of their external or even their internal organization. It deals also with their relations to conditions in time and space. It seeks out the epoch of their first appearance, and traces them through their diffusion under favouring, or limitation and final extinction under unfavourable influences. It searches for the causes inherent to their organization, by which, of two similar yet not identical creatures, the one has the power to battle with varied and very different forces, to maintain a vitality that braves the duration and complicated arrangements of several successive epochs, and, daring alike the freezing cold of the poles and the feverish warmth of the equator, to spread its individuals over more than half the world. Whilst the other, distinguished, it may be, from its congener by some apparently slight and useless difference,—though the mark be an indelible brand by which nature has stamped that member of her flock, and that one only,—is incapable of assuming protean variations, or of enduring even a slight change in the physical conditions under which it first appeared. It enjoys a fleeting existence during a short segment of time,—dies out ere it has spread beyond a mere speck on the earth's surface, disappearing never to reappear;—perchance, if it belonged to some primeval fauna, never to become known to man, with all his research, unless some bony or shelly framework gave consistence to its otherwise perishable substance.

But so to deal with our subject, so to work at natural history, how can we proceed without the aid of geology? It is plainly impossible. From the moment we recognise a consideration of the relation to time and space of species and genus as an essential element of a right and full understanding of them, from that moment the naturalist calls in geology to his

aid. And how is geology to help him? The pure geologist,—the inquirer into the earth's physical features at the different stages of its eventful history, and into the probable nature of its internal constitution and the causes of the inequalities of the outline of its crust,—the pure geologist cannot aid him, but, in his turn, rather expects aid from the naturalist. For the geologist has been taught, by his own experience, that without an investigation of the life-manifestations at successive epochs his science is fragmentary and incomplete. But the mere describing and cataloguing, the casting of them in established zoological and botanical moulds, is as likely to mislead us as to help. Such a process has misled. Half the sins of premature speculation so often called up, like filmy ghosts, to frighten incipient geologists from the beautiful science they would follow—the charges of crudeness, hastiness, vagueness, inconsistency, and inaccuracy brought against geology—have arisen from this mode of attempting to misconduct scientific inquiry. The geologist collected fossils without sufficient notes, and without a notion of their zoological or botanical value; he transmitted them to the zoologist or botanist, who examined them without caring to know whence they came, under what conditions they were found, or who were their associates. It was like the author mentioned by the novelist, who, when called upon for an article on Chinese metaphysics, read up China on the one hand and Metaphysics on the other, and combined his heterogeneous knowledge in a wordy and well-sounding but empty disquisition. The time for such manner of work is going—has gone. The naturalist who examines fossils, if he would understand them, must study and practically acquaint himself with the principles and facts of geology. The naturalist who studies living beings, if he seek to grasp the philosophy of his science, must work among the remains of extinct creatures also. Geology must become an element of his studies. There was a time—not very long ago—there may be a few holders by it yet—when it was supposed that to be a zoologist a knowledge of comparative anatomy was superfluous; that to be a botanist no acquaintance with vegetable physiology was required. That day is gone, or expiring. The man who

would now maintain such a state of things to be science is listened to with a smile, not argued with; and so will it be with all who pretend to investigate the phenomena of distribution, and the laws which determine the limits of genera and species, without a knowledge of geology.

On the principle that there is no palæontology without natural history, that there is no natural history without geology, the relations of living to extinct forms have been borne in mind in all the arrangements of this Museum, and in all the duties of those to whom the charge of the fossil collections, made by the Geological Survey, has been assigned. Moreover, in order to carry out this view to its fullest extent, the officers of the palæontological department are required to take the field when investigations demand their presence, and to study the occurrence of organic remains in the rock, as well as in the cabinet. To do this they must necessarily make themselves familiar with the practice of geological research. They must learn to appreciate the exact bearing of physical and mineral conditions on organic remains. Such, too, is clearly the method by which a knowledge of palæontology of practical value to the mining student can be acquired.

In conducting the business of this class, I look forward to the holding of field-excursions, regarding them to be quite as essential as lectures for the instruction of the student, who to benefit by his studies must become a practical fossilist, and learn to observe carefully fossils *in situ*, and appreciate on the spot the evidence afforded by their associations. During the progress of our winter-courses this can be done effectually in the neighbourhood of London, or by means of the facilities of transport afforded by lines of railroad. I trust that before the end of this session a compact band of undaunted investigators, belted, strapped, and bag-bearing, armed with stout hammers and sharp chisels, under the veteran generalship of our director-in-chief, and officered by my mineral and geological colleagues and myself, will make the rocks shake and yield up their treasures for many a mile around the great metropolis.

In teaching the natural history of organic remains, we shall enforce the practice of the observation of them mainly through

British examples. The principles of the study shall receive a wider range of illustration. But to learn details surely, we must acquire our knowledge through that which is most precisely known. We have abundant materials in this Museum for the minute investigation of the fossils of an area in a geological sense probably the most important and typical of provinces of the earth's surface. The value of the collection does not depend merely on the number of species or beauty of specimens, though in these respects we have much to boast of; it is due to the minute information preserved in our records respecting the history of individual specimens. Every fossil collected during the operations of the geological survey has a value far beyond any accident of fineness or rarity. It has been selected especially and precisely in elucidation of a geological fact. It is a lasting and ever-consultable memorandum of a geological observation. Its locality, its associates, the abundance or scarcity of individuals of the species at the spot and in the stratum where it was found, the mineral character of the rock itself, the condition of the specimen—whether indicative of entombment when alive, or of death before becoming imbedded, or of transport before reaching the spot where, invested with sediment, it became immortalized in stone,—all these points, essential to an accurate, to a scientific knowledge of the fossil, have been carefully noted and recorded; and the specimens incorporated with the survey collections are worthy associates of them. We know who collected them, and how they were collected; and before they find a place in our cabinets their history has been traced and certified.

Such materials give confidence to the student. He feels that through them he may acquire information calculated to assure him in his after researches; he imagines for himself a safe type, a standard of comparison by which to test less perfect data. If his fate should lead him to undertake geological, mining, or exploring adventures in distant and little known lands, he will find himself far better qualified to draw conclusions respecting the age and position of fossiliferous strata than if he had come to the inquiry with a vague general knowledge such as he might gather from the inspection of a universal collection; for

an intimate acquaintance with the fossils of all regions could not be acquired by him even during many years. He has learnt not only *how* to observe, but also *what* to observe; he has gone through that wholesome training which monographic exercises in any of the divisions of natural history invariably give. Without it, zoologists, botanists, and geologists must be content to take place among mere declaimers and talkers about things, which, in the absence of practical knowledge, all possible reading and lecture-listening will fail to make them understand.

The collections of organic remains displayed in the galleries of this museum are not of interest to the student only, they have a public value: they bear testimony to the correctness of our knowledge of the geological structure of the British Islands; and, where they coincide with the operations of the geological survey, present the minutest evidence of the age and features of the strata explored, as far as fossils can afford such evidence. And as the economic value of geological observations must ever depend on their strict accuracy—on the confidence that may be placed in them by those who would invest capital or prosecute researches on account of their faith in data officially laid before the public—such tangible proofs, open to the most severe scrutiny, as collections of organic remains made on the spot by the officers of the survey, must have a practical importance, upon which too much stress cannot be laid.

In a country where riches are a title to high esteem and power, any branch of science that has no direct influence upon money-making is likely to be held in low estimation by the unenlightened. The meaning attached to the word *practical* in England is often nearly synonymous with *money-producing* or *money-saving*. Although I would be the last person to maintain that scientific establishments should be supported by the nation, or scientific researches respected, mainly on account of such recommendation, I am not one of those who would separate science from the ordinary pursuits of men, or who would desire to see philosophers withdrawing themselves from the multitude, by keeping their thoughts unmingled with the meaner aims of the crowd. When science, provided she be mindful of her honour, and make no sacrifices of her love of truth, serves as

the handmaiden of even the humblest of arts, her dignity gains in lustre, and her familiarity breeds respect. There is no department of science without some ties with the common business of life. Even palæontology may have a direct as well as an indirect influence on commercial enterprises. An example or two, out of many, may serve as an illustration.

Not long ago considerable funds were spent in a district in the west in a useless search for coal. The adventurers, ignorant of geology, had set to work in dark Silurian shales, among the oldest of stratified rocks, and far beneath our carboniferous strata. Their mineral aspect, however, resembled that of certain coal-shales with which the miners were familiar. Had they possessed even a slight acquaintance with organic remains, they would have abandoned their profitless experiment at the very commencement; for the shales in which they were working were charged with graptolites, extinct zoophytes, which do not range higher than the lowest fossiliferous group, and the presence of which indicated the true character of the strata beyond question. The fossils did not escape the notice of the miners. They collected them, and grew the more confirmed in their mistake; for, unacquainted with the differences, they mistook them for coal plants. They might have bored through the earth's centre without coming to the treasure they sought; their only chance of reaching it was by perforating quite to the antipodes.

In a second example I was myself personally concerned. Some years ago, when as yet but a student attending the geological and mineralogical lectures of Professor Jameson, I opposed by letter in a provincial journal a mistaken enterprise upon which much money was unfortunately spent. The object of it was to sink through the old red sandstone, with the hope of reaching coal, in a district where such a search was hopeless. The parties engaged were confirmed in their intentions by the advice of practical coal-miners well acquainted with the collieries of the north of England. These men argued, that since there were limestone and sandstone similar to those rocks associated with coal, and overlying it, in the districts where they had worked, therefore the strata were the same, and coal should be found. I pointed out, chiefly from the evidence of the fossils contained

in the limestone overlying the sandstone, that the rocks on which they proposed to operate were only like to, but not identical with, those to which they were compared. I told them,—the warning was proffered in vain,—that they were throwing away their money. One of the shareholders, an intelligent man, and a reader of elementary works on geology, replied to my objections by attempting to meet them on scientific grounds. In some old-fashioned books it used to be asserted, that shells of the genus *cardium*,—in plainer language, cockle-shells,—when found fossil, are characteristic of tertiary strata. "Now," wrote my opponent, "cockles abound in the limestone in question, therefore it is tertiary, and the carboniferous strata must lie beneath." He had mistaken certain forms of *terebratula*, shells of a very different order, for cockles; a very unfortunate mistake, for the error was persisted in, and much good gold turned into irredeemable dust.

I have cited these instances because they not only show how serious an error, leading to considerable pecuniary losses, may be committed in consequence of ignorance of science, but also are examples of the danger of inaccurate or fancied knowledge. In both these cases the fossils were noticed, but, through ignorance of these distinctions, altogether mistaken.

There is much popular palæontology abroad, as likely to mislead as to guide. The practical value of this section of natural history depends upon its certainties, and not upon its uncertainties. In the former class may be placed the determination which fossils afford of the origin of rocks, whether they be marine or estuary or fresh-water deposits; of the relative ages of sedimentary strata; of the indications they give of the climate of different epochs; of the information they contribute respecting the ancient physical geography of our globe; of the testimony they bear to the unity, harmony, and benevolence of the Divine scheme of creation,—the same during incalculably distant centuries of primæval time as now.

Under the head of uncertainties may be ranked theories of transmutation of species; of progression towards perfection; of universal diffusion of species at ancient epochs; of the retrograde development of animal and vegetable forms in time; of original perfection and subsequent degeneration; of original

generalization of specific types, and subsequent specification; of differences in the physiological habits of creatures anciently and now. All these notions are hypothetically or theoretically advocated, more or less, by men of science at the present day. All of them, it seems to me, are at best inductions from insufficient data. They may or may not be true, but at present, as we may see by a glance at the comparative extent of our knowledge of existing and extinct forms, we are not in a condition to come to a decision on the important questions they involve.

The collections of fossils displayed in the cabinets of this museum are highly illustrative of the great truths of geology, and are arranged so as to convey instruction on the fundamental principles of the science. The fossils of each formation,—in stricter language, the creatures of each epoch in the Preadamic history of the earth's formation,—are grouped together, and each group is displayed in strict geological sequence,—in order of superposition of strata. Whoever studies these collections carefully may gain a clear conception of the nature of the proofs afforded by natural history of the vast duration of the earth, and the series of epochs, each characterized by a distinct creation of organized beings, that have preceded the present condition of animated nature.

Although in the commencement of our educational efforts we can scarcely hope to embrace all the subjects that spring out of the arrangements of this Institution, it behoves us to look forward to the utilization in other directions than that of geological science even of its natural history resources. There is a great blank yet unfilled in the teaching of the numerous applications which may be made of natural history to the arts. Charming as are the exquisite examples of ceramic, vitreous, and metallic manufactures collected in our Museum, we cannot but feel that the workman, however fine his natural or acquired taste may be, is unaware of the vast variety of beautiful shapes and designs that lie unused in the treasury of nature. The aiding of the manufacturer in the perfecting of his works is one of the aims we profess. The chemist can teach him how to improve his materials, or furnish him with new substances and new

pigments to use in his art; the metallurgist can show him those metallic compounds that can give the finest effect to his castings; the mineralogist and geologist can open out fresh stores of ore and earth suitable for his operations. Cannot the naturalist also come forth with friendly aid, and render some good service?

The relations of natural history with the arts are of two kinds, either illustrative or suggestive. To the first belongs the inquiry into the nature and sources of the numerous products derived from the animal and vegetable kingdoms, and applied, or capable of being applied, as direct materials for arts and manufactures. A more perfect acquaintance with old and a discovery or indication of new materials adapted for the exercise of human skill and workmanship may thus be attained. But the naturalist may render higher and at the same time as practical services to the craftsman, by furnishing out of the endless store of beautiful objects that are rendered familiar to him by his scientific pursuits sources of new and exquisite design,—fancies originating in the teeming brain of nature,—God-born thoughts, that become manifest in living shapes,—all consistent,—never jarring,—in every part admirably adapted to each destined purpose. Now the laws of these adaptations and harmonies, the proportions by which the beauty of living things is maintained, the ideas by which similar forms have been grouped in nature, and, though like exceedingly, yet wondrously dissimilar,—these are among the earnest studies of every philosophical naturalist. Surely out of such studies lessons applicable to art may be derived! What is ornamental art but the isolation and embodiment in works of human skill of the beauty that is diffused through all the works of God? And that beauty lies, not merely in the bulk of objects, nor on their surface, but is as manifest in every part and atom composing them as in the combined whole. It is in itself composite; the combination, not of lesser, but of minuter beauties. To imitate,—to approach,—we must attempt a like arrangement, in order to obtain the same exquisite result. And how, except through earnest and scientific study, can we attain the knowledge that shall enable us to discover the pathway leading towards perfection?

On the Importance of Cultivating Habits of Observation. (*The Introductory Lecture to the Course on Mechanical Science. Session* 1851—1852.)

By Robert Hunt, Keeper of Mining Records.

In studying the phenomena of human progress we discover much that is of the highest interest to the philosopher, as illustrating the manner in which the powers of mind have been turned to the investigation of the works of creation, and displaying, at the same time, the beautiful re-action of each discovered truth in the improvement of man's social state.

The past must ever be the teacher of the present, and a bright or clouded future is entirely dependent upon our appreciation of its teachings.

Man, gifted with exalted powers, is the inhabitant of a most wonderfully constituted world, and according to the industry with which he exerts his reason he becomes the possessor of its wealth.

The animal necessities of the race are the primary exciters of the reasoning powers, and we find uncultivated man exerting his intelligence only to snare and destroy beasts, to furnish him flesh for food, or skins to shelter him from atmospheric changes. From this state he advances to a pastoral one, and studies to lessen his toils by domesticating animals, and thus escape from the perils and uncertainty of the chase. In the repose of a shepherd's life habits of contemplation appear to have had their earliest birth, and the phenomena of nature to have interested the human mind. Attention once awakened to the ever-changing, still recurring operations of organic life,—to the mysteries of alternating light and darkness,—the gradual and regular passage of the seasons,—the beauty of the stellar vault,

and the meteoric displays which are for ever occurring in the earth's atmosphere,—an imperfect science slowly crept into existence, the full development of which was long retarded by the misty superstition with which man invested all things that he could not comprehend.

Without attempting to analyze the psychological progress of man in his study of the exacter sciences, which will, however, be found to be dependent upon his habit of methodizing ideas, we may, by confining our attention to the simple discovery of natural truths, see that all advancement has been the result of *experience.*

Facts frequently returning have at length solicited attention, and thus is cultivated habits of *observation.* By close attention new features are discovered in the phenomena; results which had long escaped casual and heedless glances are developed, and the mind is thus led up to the inquiry after the exciting cause. True science now begins, and the evidences of *experiment* are sought. A philosophical method is eventually developed, and its operations are displayed in the careful classification of observed phenomena, in the consideration of which the human mind necessarily demands the assistance of *theory;* and as this is constructed in accordance with true observations, or in obedience to the exuberant thoughts of an imaginative mind, is the discovery of truth accelerated or retarded.

To the record of careful observation we owe the first or initiative idea of every truth. The earliest duty, therefore, of every teacher is to train and educate the mind in habits of close and exact observation.

Man cannot create, but he is endowed with powers by which he may examine everything which is created, and by combination produce results which are to the uninitiated but little short of a creation, when applied to the amelioration of some of the necessities of mankind. Human intelligence has bound the physical forces to do man service, and all the great applications of science may be referred to in proof of the position that human progress is directly dependent upon careful observation, and the habit of recording, in a systematic manner, the facts which have been thus developed to the mind.

The history of every science affords examples of this; the devious and uncertain wanderings of the astrologer, the alchemist, and the cosmogonist exhibit the severe struggles of truth through the mazes of imagination; while the advancement of astronomy, of chemistry, and geology may be appealed to as expressive of the advantages of working diligently with a system of observation for our guide, and waiting patiently for the development of the truth.

It has been said, and said too by a great authority, that in experimental science we owe much to accident. Depend upon it, however, as a general rule, there are no accidents in science. It is true that often in the progress of an investigation an unexpected circumstance gives rise to a new train of inquiries; new ideas are the result, and discoveries the consequence: if that which may be regarded as an accident does not generate a clear idea, and generalize a correct system of inductive search, it remains a valueless fact.

Thales of Miletus observed, that amber being rubbed attracted light bodies. Here was a fact, probably of accidental discovery, which failed to produce a definite idea; and remember, nearly 2,000 years passed away before man detected the truth that the *electron* of the Greek philosopher was a source of the all-diffusive agency, electricity. Galvani noted the convulsive movements of frogs, when the moist surface of their bodies was in contact with two metals of unequal affinity for oxygen; this generated a correct idea in the mind of Volta. Step by step induction has followed in this path, and we have, within a period of sixty years, the discovery applied to metallurgical processes of great utility, and to the valuable one of firing simultaneously any number of holes in the operation of blasting rocks, by which the sinking of shafts and the driving of levels in our mines are carried on with great rapidity and much economy. Following on the same tract Œrsted proved that a copper wire under the influence of an electric current became a temporary magnet. It was soon shown that an iron bar placed within an helix of such wire acquired most powerful magnetic properties; and within twenty years this knowledge has been applied to measure the tread of time, and to be the winged messenger of

human thought, surpassing beyond all limits the speed of the "tricksy Ariel," and leaving the hurrying tempest like a laggard in its path. These facts were adduced by my colleague, Dr. Playfair, in support of his arguments when discoursing of the value of abstract science; but as it will be my duty to show you in the progress of my course the experimental evidence to which reference has been made, I have not hesitated about repeating the striking illustration which these physical forces lend to the position I maintain. I cannot allow the present opportunity to pass without drawing attention to the evidence afforded by the attempts which have been made to apply the electrical element as an illuminating and mechanical power, of the danger of attempting to do so before we have acquired an accurate knowledge of all the phenomena which are involved in the conditions of the application. In the arc of light produced between the poles of a powerful voltaic battery we obtain the most vivid illumination which can be produced by artificial means. Ingenious mechanical contrivances have been devised to render the distance uniform between the charcoal points, which form the polar terminations of the wires, and thus to give steadiness to the electrical light, but since there is a constant transfer of the solid element from one pole to the other, the required steadiness has not yet been obtained. The question of the economy of this application, even if successful, may be conveniently embraced in connexion with the consideration of the application of electro-magnetism as a motive power. It has been stated, and is indeed now well known, that we can obtain an enormous attracting and repelling force by the agency of electro-magnets. In some cases magnets have been placed upon the periphery of a wheel, while others have been fixed upon a firm circle surrounding it. By mechanical contrivances the polar disposition of the magnets has been rapidly changed. The consequence of this is the exercise of an attracting and repelling power, by which the wheel is driven swiftly round. Another form of construction, offering some advantages, is a cylinder, around which clothed copper wire has been coiled, thus forming a hollow magnet, into which another solid magnet representing a piston is drawn, and from which, by changing the

poles, it is afterwards repelled. By this means a long stroke is obtained, and by a crank any kind of machinery set in motion.

The first difficulty which has to be encountered here is the very great rapidity with which the power diminishes through space. An electro-magnet which will sustain 220 pounds when the armature is in contact with its poles, exerts an attractive force of 40½ pounds when the armature is at a distance of one fiftieth of an inch only. Now you will perceive that under any of the arrangements which have been adopted the moving and the fixed magnets could not be brought nearer together than the fiftieth of an inch; hence there is an immediate loss of four fifths of the power we have produced.

The second difficulty to which I had the satisfaction of first directing attention in this country, although I have since been informed that it had been detected by Jacobi, is, that the moment the magnets begin to move there is a temporary loss of power, or, perhaps, it would be more correct to say, there is a development of an opposing force, by which the mechanical power is again considerably diminished; and the greater the speed with which the magnets move, the more rapidly does this decline. The report made by order of the American government on Professor Page's electro-magnetic engine directs attention to this fact, which the reporting engineers were not able to explain. Mr. Hjorth, the most recent inventor and patentee of electro-magnetic engines, after the publication of my paper, observed the influence of these induced currents, and with a view to economy endeavoured to employ them in effecting the precipitation of the zinc, from the sulphate of zinc formed in the voltaic battery employed, but without success. Such are the difficulties which at present stand in the way of applying electricity as a motive power. It may be said, that these resolve themselves into questions of economy. Granted. The whole of this question I have investigated with the closest care, and the result is, that a grain of coal consumed in the boiler of a Cornish steam engine will lift 143 pounds one foot high, whereas one grain of zinc consumed in the voltaic battery will lift but 80 pounds through

the same space. Now the cost of zinc is 216*d.* per cwt., while the cost of coal is but 9*d.* per cwt. It will be my duty to show and explain early in the present course of lectures that the development of power, of whatever kind, is always accompanied by a change in the form of matter somewhere. To obtain a given amount of exertion from a horse we learn that it is necessary to give him a larger quantity of food than when he is at rest. If we desire to impel a locomotive engine at a high velocity we are compelled to supply an increased quantity of fuel, that steam may be generated with greater rapidity. We know of no development of force, whether heat, light, electricity, or muscular power, without such a change in the form of matter as amounts, to us, to its destruction. Muscle is consumed in every exertion of animal strength. Carbon and hydrogen in like manner are burnt in producing our artificial lights, either as gas, oil, wax, or tallow, and also in the production of heat, whether in our domestic fires, the furnaces of our manufactories, or the boilers of our steam engines. We evoke electricity by several methods of disturbance, but we have only now to consider that means of development which depends upon chemical action. Although we employ magnetic force, this is dependent on the power which is produced in the voltaic battery, and the zinc or any other element which may be employed is converted into some new form. Zinc, for example, is changed by the action of sulphuric acid in the battery into sulphate of zinc; and the advocates of the application of electricity as an illuminating or moving agent on the ground of economy state, and truly state, that the salt may be reduced and the metal revived. From my investigations of the whole question I feel assured that I state a truth in saying the coal employed in reproducing the metal would afford as much light, heat, or mechanical power as that obtained by the destruction of the metal in the first instance in the battery.

Let me not be misunderstood. In the present state of our knowledge I deem it hazardous to attempt to apply electro-magnetism instead of steam. Notwithstanding the rapid discoveries made in every branch of electrical research, and the great power which we can command in our voltaic arrangements,

it must not be forgotten that the quantity of electricity obtained is exceedingly small in comparison with the quantity which exists in the elements constituting the voltaic battery. Dr. Faraday, whose experimental researches in electricity must be regarded as the finest example of inductive investigation to be found in the annals of British science, and the most perfect exemplification of the philosophy of Bacon to which the student in physics can be referred, has proved that a single drop of water holds imprisoned in its liquid chains a quantity of electricity which equals that contained in an ordinary thunder-cloud. In every form of the voltaic battery a very large quantity of electricity is lost in passing from the liquid to the solid element, and the contrary; so that in overcoming the resistance nearly three fourths of the power is consumed.

Allow me to give another example of the value of close observation in connexion with magnetism. Dr. Faraday was the discoverer of the fact, that when a hollow helix of copper wire containing a core of soft iron was moved in front of or near the poles of a permanent steel magnet, electricity was evolved, and all the results of voltaism readily produced. Hence the formation of magneto-electrical machines; and in the great electro-plating establishments of Birmingham we may see the process carried on by the current thus generated by the revolution of coils of copper wire placed on an iron armature near the poles of an ordinary steel magnet.

To the true philosopher everything, howsoever insignificant to ordinary minds, is felt to deserve attention, and the minutest phenomena claim the most accurate study. A body falls to the ground,—a drop of water hanging from a rod, or resting on a leaf, assumes a spherical form. Nature is asked, Why is this? and the answer is the discovery of the law of gravitation, by which power each planet is retained in its orbitual path around the sun, and the entire solar system, held as completely in union as the particles of the water-drop, moved through space under the influence of a gravitating force resident in some far distant and probably unseen star. Reflection on the discovery of the planet Neptune must lead to the conviction of the truth of the Newtonian law of gravitation.

Up to the year 1804 the planet Uranus moved in its orbit without any appearance of disturbing influences; but at that period an accelerated motion became evident, and this continued until 1822, when the planet's rate of progress was retarded, and this has continued to the present time. It was felt that according to the law of planetary disturbance, the gravitating action of Jupiter and Saturn not being sufficient to explain the perturbations, it was probable that a mass of matter exterior to our known system was the exciting cause. In this state of the question the following problem became the subject of investigation to Mr. Adams, in England, and M. Leverrier, in France, unknown to one another:—"*Given the disturbances to find the orbit, and place in that orbit, of the disturbing planet.*" These geometers arrived at conclusions differing from each other only 3° 19′; and M. Leverrier having announced to Dr. Galle, of the Royal Observatory of Berlin, the position in which a new planet,—the disturbing cause,—should be found according to his calculation; on the very night of the day on which the letter was received the astronomer of Berlin discovered the planet Neptune in a point of space differing only 47′ from the mean of the two calculations. The planet Neptune, like the old planet Saturn, is surrounded by a ring. Allow me for one moment to direct attention to some experiments by Plateau on the condition of bodies relieved from the influence of gravitation, which appear to show that the remarkable phenomena of these two planets, with their luminous rings, are due to the influence of motion exerted under peculiar conditions. If oil is dropped upon water it swims; if upon alcohol it sinks; but if we make a careful combination of water and alcohol we obtain a fluid of the same specific gravity as the oil, and the globule of oil will swim in the very centre of the fluid, a perfect sphere. If into a properly arranged glass box we pass a fine wire through the sphere of oil, and by means of a handle cause it to revolve slowly, the sphere becomes an oblate spheroid; by increasing the motion we flatten it still more, until at a certain rate of revolution it becomes a disc, when a ring of oil is thrown off from the central globule, and although separated by intervening water, it revolves at precisely

the same rate. It is not a little interesting thus to find mechanical science affording us the means of explaining the grander phenomena of creation.

The force of gravitation has its practical application in the ordinary forms of water-wheels, the falling water producing a continuous circular motion. In the hydraulic pressure engine, of which we have a beautiful model in the museum, the gravitating power of the water is the moving force. In the windmill we see the operation of the same power; and in the earlier engines, as those of Newcomen, Savery, and Watt's first single acting engine, the return of a heavy mass under the influence of gravitation and the atmospheric pressure—a result of the same principle—was the leading element of power. The works of Archimedes and of Hiero of Alexandria show us that the ancients were well acquainted with the operations of this agent, although they had not arrived at any correct idea of its law of action. It is to a neglect of the laws of gravitating force, and of the principle of action and re-action which prevails in every mode of motion, that the idle problem of producing perpetual motion has so frequently led ingenious minds aside from the path of usefulness which they would otherwise in all probability have pursued.

To continue our examination of the importance of minute observation, every step of progress from the employment of steam to produce a continuous motion, by Ptolomy Philadelphus, 130 years B.C., to the discovery by Watt of the expansive force of steam in 1782, might be quoted in exemplification.

We find Branca and Kircher employing the force of a jet of steam to drive the vanes of a wheel.

Baptista Porta observed the pressure exerted by confined steam, and he used it to raise water.

The discovery of the pressure of the air, and the investigations of Torricelli, Pascal, Guericke, and Boyle, led to the construction of engines by Worcester and Papin, in which the elastic force of steam and atmospheric pressure were combined in action.

Thomas Savery, carefully studying all that had been done previously, appears to have first conceived the correct *idea* of the force, and to have applied it with much greater success than any

of his predecessors. In 1698 he got a patent for his discovery, calling it an invention "*for raising water, and occasioning motion to all sorts of millwork, by the impellent force of fire.*"

Newcomen, an ironmonger at Dartmouth, associated himself with Cawley, a plumber of the same place, and they together carefully investigated the phenomena of atmospheric pressure, and the formation of a vacuum by the agency of steam; and Newcomen certainly transformed an imperfect, and for many purposes a useless machine, into a really efficient steam engine, which could be applied profitably and safely to the most important uses. Newcomen should share a pedestal by the side of Watt; the ingenious contrivances of the obscure ironmonger of Dartmouth, the result of minute observation, have had much to do with the advance of civilization.

Of the inventions of Watt it is scarcely necessary to speak; the fertility of his genius is known to all; and the history of his progress informs us that every advance made by James Watt was a comment on the text I have chosen,—the value of observation. Of the importance of the inventions of James Watt well may Arago, in his Éloge, speak as follows:

"We have long been in the habit of talking of the age of Augustus and of the age of Louis XIV. Eminent individuals amongst us have likewise held that we might with propriety speak of the age of Voltaire, Rousseau, and Montesquieu. I do not hesitate to declare my conviction, that when the immense services already rendered by the steam-engine shall be added to all the marvels it holds out to promise, a grateful population will then familiarly talk of the ages of Papin and of Watt."

Heat, as a force or principle, most intimately connects itself with the steam engine, and we are hence led on to a consideration of some of the phenomena which are associated with calorific action. Water at the level of the sea boils at 212° of Fahrenheit when under ordinary conditions. The minute observations of a Belgian engineer have led to the discovery that when water freed from air is exposed to heat, ebullition does not commence until it arrives at a much higher temperature, and that then it occurs with almost explosive violence. He has also proved that if water in this state is brought to the temperature of 250° or

260°, and then a single drop of water containing air be allowed to fall into it, that the whole volume becomes agitated in a terrific manner, that indeed an explosion occurs.

Who amongst the thousands inhabiting those regions of the earth, where water is rendered solid by the reduction of the winter temperature, but has noticed the air bubbles enclosed in the transparent ice? None of these thousands discovered a great fact in this until Professor Henry was led to examine it. The result of that investigation has been the discovery of the remarkable truth, that water in the process of congelation actually squeezes out everything it may hold in solution, and becomes far more pure than it can be rendered by any other means. If water holding air, colouring matter, or saline bodies in solution is, while being frozen, kept in a state of slight agitation, the air, the colour, and the salt are all rejected alike, and a tasteless, colourless, transparent ice remains. It is curious to see how near a great truth men often are, and how long they allow it to escape them. It has been the constant practice of the Russian nobles to place their wines in ice until they were frozen, for the purpose of obtaining the small quantity of ardent spirit left in the centre of the mass. The water of the wine in freezing liberated the alcohol and flavouring matter, and a pungent cordial was thus obtained.

Ice thus free of air, if melted out of contact with the atmosphere, may be heated to nearly 300°, when, instead of boiling, it explodes. How nicely balanced are the conditions of all things in nature! We now learn that if water was not the all absorbing body which it is, it would be as dangerous to expose it to heat as gunpowder or any other explosive compound. This interesting discovery promises to throw some light upon many of the steam-boiler explosions, which will form a subject of inquiry in the present course. As another illustration of the manner in which we have, from the defective character of our education, allowed phenomena continually presenting themselves to us to escape attention, look to the investigations of Boutigny. That drops of water thrown upon hot iron arrange themselves into spheroids, and move about with a peculiar internal motion, is nothing new. Yet who amongst us suspected that these

dancing drops were telling a story to man which will in all probability completely change our ideas of the properties of heat?

If two similar metal vessels are taken, and one is filled with water, which is allowed by the action of an ordinary fire to boil in the common way, we know what then takes place; but if we allow the other to become red-hot before we fill it with water, and when full maintain it at a red heat, the water will never boil. The former vessel will soon be emptied by the evaporation of the water in ebullition, but that water in the red-hot vessel forming itself into a spheroid, rolls about, it never gains a higher temperature than 150° or 160°, and it evaporates but slowly. Again, at the temperature of red-hot iron chemical affinity is suspended, and if we project into an iron crucible thus heated, many bodies having the most powerful affinity for each other, they will not enter into combination, but remain separate spheroids rolling around each other. The investigations of Boutigny in this path have proved that the repulsive power of heat at elevated temperatures is so great that the naked hand may be plunged into melted iron without injury, and that the wondrous feats of the Magians and the tricks of the conjuror can be performed with impunity by the philosopher. No less than three patents have been taken out in England for generating steam with great rapidity. In one water was dropped into red-hot tubes, in another it was thrown upon red-hot plates of iron, and in another heated mercury was employed. It was thought that the water would be *flashed* into steam, and an immense power obtained, but in every instance failure followed the experiment. The investigations of Boutigny show the cause of failure, and prove the importance of experiment at every step we make in our endeavours to employ the great powers of Nature to do us service. Recently in France attempts have been made to employ water in this spheroidal state to work a marine engine. It being thought that as the vapour which escapes from the spheroidal water is of the high temperature of the surface upon which it is formed, that it would, from its extreme tension, furnish an enormous amount of power. The experiment has not been, even in this case, successful hitherto.

Mr. Woolfe, to whom the Cornish steam engine is indebted for many improvements, once tried an experiment in the presence of Mr. Davies Gilbert and some other gentlemen of a very remarkable kind, the result of which bears in a striking manner on the investigations alluded to. A measured quantity of water was placed in a boiler, all the safety valves were most carefully closed, and every chance of the escape of steam prevented. The fire was now got up, and for some time the steam gauge indicated a regularly increasing pressure. At length, to the surprise of all, the pressure was seen slowly, but gradually, to diminish, and although the boiler plates became so hot as to char the wood which surrounded them, this remarkable phenomenon continued, and when the boiler had cooled it was found that no water had escaped. These investigators conceived no correct idea from this hazardous experiment, but it was the Caignard de la Tour experiment of enclosing elastic fluids in hermetically sealed tubes, repeated on a large scale, and it showed, as all the experiments of Boutigny show, that notwithstanding our boasted knowledge we are yet ignorant of the laws which govern the operations of heat when its excitation is elevated. The decomposition of water by heat, as discovered by Mr. Grove, belongs to this class of phenomena, and Dr. Robinson, of Armagh, in considering the experiment, speculates on the probability, that at a certain point *heat* may be changed into a *chemical force*, similar to those radiations from the sun which effect the changes now familiar to all of you in the photographic processes, to which the term *Actinism* has been generally applied.

Although it will be my constant endeavour to explain with all care the useful applications of science; to show how thoroughly associated science and practice should be, I shall never fail to direct attention to those experimental evidences which enable us to interpret the great phenomena of nature. As a cultivator of physical science I feel that half of the advantages to be derived from the study would be sacrificed, if the satisfactory manner in which advancing science opens out to the contemplative observer new harmonies in creation, and tends to exalt the mind to higher and holier aspirations was not shown.

In connexion with heat, observation has proved to us numerous important points relative to its distribution over the earth's surface. The Isothermal bands connect themselves with the phenomena of animal and vegetable distribution; and still more strikingly we are beginning to discover an intimate connexion between those regions of mean equal annual temperature and the great phenomena of terrestrial magnetism. The conditions of the ocean currents,—as, for instance, the Gulf stream setting northward from the Gulf of Mexico, and ameliorating the conditions of our own winters,—are worthy of careful study. The waters of the sea upon our western shores are always several degrees warmer than the adjoining land, and during last winter the ocean temperature was found to be two degrees higher than usual. May not the mildness of that season have been due to the influence of that current of water, warmed in inter-tropical climes, flowing northward, and yielding up its store of heat to the shores of these islands?

This ameliorating influence is strikingly shown in Norway. On the southern coasts of that country, which are sheltered from the Gulf stream by our own islands, the cereals will not grow; but further northwards, where the great current setting to the north of Scotland reaches the Norwegian shore, the climate is rendered sufficiently mild for the growth of grain crops.

Again, the trade winds and the monsoons are entirely dependent upon the operations of heat; and careful observation has shown that the tornadoes of the West Indies and the cyclones of the Indian Seas are entirely due to the action of currents generated by the intensely heated surface of the earth. Notwithstanding the valuable researches of Sir William Reid, and others, proving the rotatory character of these storms, I am not satisfied that we have yet had a correct theory of the physical causes in action to produce them.

These storms are revolving masses of air, with currents rushing from the circumference to the centre, and blowing up through that centre; these systems of air in violent motion being sometimes many hundreds of miles in diameter.

The simplest explanation appears to be, that a comparatively small column of air is formed by contact with the heated earth,

which ascends with much rapidity. Take the example of a jet of steam, which in rushing from a boiler under high pressure draws all surrounding light bodies into it, and urges them upwards; the same phenomenon is shown in rapidly flowing water. The jet generates rapid currents on every side; these increase the diameter of the moving mass, and it progresses, continually increasing in size; all the currents rushing in towards a moving centre, and upwards through that centre as through an inverted tunnel. The barometer is the truthful indicator of a diminishing pressure as the centre of the storm approaches the place of observation; and thus the mariner is, by careful attention to this instrument, enabled to determine the exact position in which his ship may be placed relative to that centre.

The importance of a knowledge of the Law of Storms, and consequently of the means of escaping from the influence of these hurricanes, and of indeed employing them to aid the ship's progress, cannot be overrated. The development of the Law furnishes a fine instance of the value of observation.

Examples of a similar kind might be quoted in connexion with electrical science. Careful observation has dispelled the erroneous idea of metals being lightning attractors; and we must be charged with negligence if we allow any elevated building to be without its pointed rod, by which the thunder cloud may be quietly discharged. The lightning is no more attracted by a pointed metal rod than is the rain falling upon a housetop attracted by the pipes placed so as to allow the water to flow to a lower level; the rods furnish the channel through which the electricity freely flows; and tower or ship may be surely protected if provided with bands or rods of copper sufficiently large to carry off the accumulated electricity, and to restore the equilibrium of forces.

The electricity of mineral veins has been a subject of much interest; it having been supposed that the currents detected were indications of the operations of this agency in producing the metalliferous deposit. From my own investigations in the principal mines in Cornwall I am disposed to consider these electrical currents as due to the chemical decomposition going on within the lode itself. It must, however, be admitted that

the peculiar disposition of dissimilar ores within the same mineral lode, the alteration in the character of the lode or vein after a dislocation has taken place, the generally uniform direction of lodes, and many other phenomena which it will fall to the province of my colleague, Mr. Warington Smyth, to describe, appear to show the probability of such a power as electricity, in some of its modifications, being the exciting agent. This is one of those extensive subjects which yet remains open for the investigation of an intelligent and industrious observer.

In a course of lectures which is to embrace a consideration of the physical forces the phenomena of the solar radiations cannot be omitted. The practice of photography belongs to these, and furnishes another choice example of my text,—the value of observation. The alchemists observed that a certain salt of silver was blackened by the solar rays; but as this did not generate in their minds any correct idea, the truth thus discovered lay dormant for ages. Eventually the Swedish chemist Scheele discovered that a certain class of the solar rays only possessed the property of darkening this salt of silver. Following in his tract, M. Berard at length, by an important series of researches, determined the extent of chemical action at either end of the solar spectrum, and speculated on the probability of light and the radiations producing chemical change being dissimilar agencies. These investigations led up to the first photographic experiments which were made by Wedgwood of Etruria, which, although not successful, as far as the fixing of the pictures obtained, were interesting examples of the production of images by the pencil of the sunbeam. Niepce and Daguerre, and more recently Fox Talbot and Herschel, investigated the phenomena of chemical change as produced by solar radiations; and the perfection of all the processes of photography is the reward of the careful observation of the change of colour produced in a white compound of silver and chlorine. Omitting, however, all mention of the useful applications of photography as a means of making philosophical instruments self-registering, allow me to state that a careful investigation of the thermic influences of the solar spectrum, associated with a physical analysis of various trans-

parent media, led me to the discovery of a glass, but slightly coloured green, which possesses the property of separating and keeping back a class of solar rays remarkable for their scorching power, and which, without obstructing any of the necessary radiations, thus protects the tropical plants in the great conservatory of the Royal Botanic Gardens of Kew from the injurious influences of scorching sunshine.

The solar spectrum exhibits several distinct phenomena. Light, heat, and chemical action are evident; and these give rise to electrical disturbance. Beyond these a class of radiations have been detected, which have the combined action of the heating and chemical rays, but which are in many respects dissimilar to either. These rays increase in quantity relatively to the other principle as the seasons advance; they being most abundant in the autumn; when, in all probability, they perform an important part in the ripening of fruit. These are the rays which, it has been found, operated to produce a kind of scorching on the leaves of those plants which grow in houses glazed with a white glass. To obviate this, was the problem submitted to my care; and the suns of two summers and autumns have shown that my experiments did not deceive me. No case of scorching has taken place upon any of the plants in the beautiful palm-house in Kew Gardens. It is important to state that an entire absence of manganese in the manufacture of the glass is demanded, and that the addition of a small quantity of oxide of copper is required.

Did time permit me I might proceed to show you, that even those discoveries which have most the character of accidents, as that of iodine by a soap-boiler, and of the beautiful blue pigment, ultramarine, in the manufacture of soda, ceased to be so by generating ideas which led to their scientific investigation. Iodine and artificial ultramarine form large branches of industry, both having resulted from careful observation; and in the latter instance we have produced a pigment which formerly cost eight guineas an ounce, but now to be obtained for less than eight shillings a pound. Learn to observe closely and accurately, and numerous other similar results must be the reward.

Mechanical science embracing a consideration of all the means of employing the powers of Nature to aid man in subduing Nature, is necessarily a wide field. It will be my object in the first course of lectures on applied Physics to deal simply with the rudiments of our science, advancing gradually to the higher phenomena. To show the intimate connexion of science and practice, the one aiding and advancing the other, will be my constant care, and in expounding the discoveries in Natural Science I hope to lead the mind to the study of those ennobling truths which constitute a

> " Divine Philosophy!
> Not harsh and crabbed as dull fools suppose,
> But musical as is Apollo's lute,
> And a perpetual feast of nectar'd sweets,
> Where no crude surfeit reigns."

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On the Science of Geology and its Applications. (Being the Introductory Lecture to the Course of Geology. Session 1851–1852.)

By Andrew C. Ramsay, F.R.S.

Centuries have passed since some of the more obvious of geological phenomena first began to attract the attention of a few of the early cultivators of natural science; but it was not till after the revival of literature in Europe, that some of the subjects contained in the wide field of theoretical geology began to be actively canvassed by many bold and inquiring spirits. For nearly three hundred years numerous authors touched upon the subject in their writings, or devoted elaborate treatises to its illustration: the works of such men as Fracastoro, Leonardo da Vinci, Steno, Scilla, Colonna, Moro, and Generelli, in Italy; of Palissy and Marsilli, in France; of Raspe and Fuchsel, in Germany; of Woodward, Ray, Hook, Strachey, and Mitchel, will ever be interesting to the student who delights to trace the early development of the science: and though its progress was slow, (down almost to the time of some of the living fathers of a more advanced geology,) yet great was the benefit it derived from the interest excited by the continuance of speculation, whether true or false. Few believed, yet little by little some scattered truths were elicited, which by degrees prepared men to throw aside the prejudices that restrained them from grappling with the subject in the only manner that could ensure its full development. For geology was not so fortunate as chemistry, when princes vied with each other in the encouragement of alchemical discovery. There was nothing heretical in the transmutation of baser metals

into gold. Geology, on the contrary, was long esteemed a pestilent heresy, and though its cultivators escaped the prison, yet, even to our own day, a few angry men are not found wanting, who, steeped in ignorance or a mistaken zeal, still re-echo the time-worn cry. For all purposes of the continuance of error, that time has however passed away, and educated people cease to regard as dangerous, and the disturbers of truth, those who follow to the utmost the legitimate investigations in physics and natural history opened out by the comprehensive labours of the geologist.

No science, save chemistry, has in the same short time made such rapid advances as geology. While the former began to assume its true position under Black, Cavendish, Priestly, and Lavoisier, geology received a new stimulus in the grand generalizations of Werner, Hutton, Cuvier, and Smith; and of late years so rapid and wide-spreading has been its progress, that no single mind can grapple with all the details of its numerous branches.

Of these the chief are:—

1st. Physical geology.

2nd. Palæontology.

The first deals with the nature and modes of formation of rocks, such as the laws that regulate and have regulated the origin and manner of distribution of strata, the nature of subterranean heat, its present and past effects beneath the surface of the globe, and the exterior igneous phenomena dependent on its operation; the disintegration, slow movements, or more violent disturbances traceable to these, or other causes, of which the present configuration of land and water is the sum; and the means consequently yielded by these apparent breaks in the continuity of order, of demonstrating the law of the superposition of strata, and of succession in geological time.

Here it is that palæontology, or the history of the old life of the world, comes to our aid. The time is not very far removed when, under such names as glossopetræ, cockles, and petrifactions, those wonderful organisms that abound in rocks, were confounded by the curious with crystalline and other mineral

substances; and though Hook had hinted at, and Fuchsel almost pointed the way, it was not till William Smith clearly enunciated the doctrine of the characterization of masses of superimposed strata by distinct assemblages of fossils, that their study acquired that scientific value by means of which the geologist is enabled to identify groups of strata, though broad oceans roll between. Miscellaneous heaps of organic remains, collected without reference to their geological locality, have no longer any beyond an accidental value to the scientific geologist, nor can an earnest worker in the broader fields of the science now afford to consider the labours of the palæontologist as extraneous to his object. They are indissolubly linked together; the evidence afforded by each is indispensable to the other; and though a man may be a geologist without being thoroughly versed in palæontology, yet if he wish to qualify himself for work, whether economic or theoretical, that may extend beyond the petty details of mere local operations, he will find it needful to be acquainted at least with the principles of palæontology, and to familiarize himself with the general groupings of the organic forms preserved in the larger subdivisions of the strata that constitute by far the greater proportion of the rocks composing the crust of the earth.

So also in mineralogy, a science that by many has been looked on as a mere branch of geology. Viewed in such a light, geology being the history of the earth, animate and inanimate, we might well ask, how many are the material sciences that do not, directly or indirectly, spring therefrom? No man considers comparative anatomy a mere branch of geology. Nevertheless it is an essential ally. So is it with mineralogy, the modern progress of which rather throws it into the domain of physics and chemistry; for, though the natural substances with which the mineralogist deals all constitute parts of the crust of the earth, they yet include many a form that rarely or never comes under the observation of the geologist. Still, the exterior mass of the earth being formed of minerals in one state or another, the study of mineralogy is indispensable to the geological student.

The same may be said of chemistry, which now begins to throw a little light on some of the more obscure problems of

geology; as, for instance, the metamorphism of rocks, and the theory of volcanoes; a fine example of which may be cited in the beautiful investigations of Professor Bunsen, in Iceland, where some of the chemical processes consequent on volcanic action may be studied on the spot, thus aiding in the explanation of phenomena exhibited in volcanic districts of all geological ages.

The true bearing of the first part of these observations at once becomes apparent when applied to a passage in the history of geology. Before the time of Werner, more than a century was required to elicit the scattered facts and generalizations deduced by previous observers. Of Werner it might be said, that "his merit consisted in this, that he infused into the body of the science a new spirit."* The breadth of his views respecting the universal superposition of strata, his application of their structure to mining, and the eloquent sincerity with which he advocated his doctrines, raised an enthusiasm that spread over the continent of Europe, and gained numerous disciples to the cause.

This, perhaps, more than counterbalanced the prejudice suffered by our science in the promulgation of the erroneous hypothesis that the ancient rocks of every description were successively deposited over the whole earth, from aqueous suspension or solution in a "chaotic fluid." The very excitement roused by the bitter controversy maintained between the followers of Werner and the more philosophical disciples of Hutton, brought constant accessions of inquirers into the field, whose opinions, right or wrong, kept up a continued interest in the subject, till, weary of controversy, the very keenest advocates of the most exclusive Wernerian theories began to see the necessity of grounding their speculations on a more rigid examination of facts.

Of all the men that have heretofore illustrated the science of geology none is greater than Hutton, whose name was so long used as their watchword by the opponents of the Wer-

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* Liebig's Letters on Chemistry, 1851. p. 26. Said of Lavoisier.

nerians. He at once threw aside the minor proofless speculations with which older writers bewildered their readers, and by the strict union of observation and generalization, his comprehensive mind grasped the main outlines of the physical section of the subject, and brought geology within the pale of inductive reasoning. Not a scrap of illustrative map or section, and but little of local description, accompanies Hutton's "theory of the earth;" and therefore, (harmonizing as they do with the detailed field work of later geologists,) his generalizations read almost as if dictated by a prophetic spirit—an impression not diminished by his massive and somewhat obscure diction. There wanted but one discovery to give that direction to the science which has led to the present high point of knowledge, I mean the doctrine of succession of species in time. Nevertheless, even had Scotland been a country geologically favourable to the easy development of that doctrine, it may be doubted, whether Hutton's mind was so modelled that it would spontaneously have entered on such an investigation. He perceived the great truth, that from the waste of continents, broad and thick contemporaneous deposits, containing the relics of life, are being formed in the seas, and that in all traceable past time the same laws have prevailed; but he knew not of the existence of a rule by which, independently of mineral character, contemporaneous strata may be identified, although widely separated from each other. The germ of this truth is, indeed, contained in the writings of an earlier writer (Fuchsel); but when he lived, the progress of discovery had not sufficiently prepared the way for its reception; and it is to the independent observations of that "great original discoverer" William Smith, that we owe the first clear enunciation of the law of the stratigraphical succession of species—a law alike great in theoretical results and in the strictly practical applications arising therefrom.

In the whole history of geology there is no chapter more touchingly interesting than the manner in which Smith arrived at his conclusions. From the moment the light first dawned on him, he never ceased to follow his convictions, with unflagging patience, industry, and energy, full of enthusiasm, undaunted by difficulties, or by the little heed that for many years was paid

him by the celebrated men, the results of whose subsequent work are in great part based on his discovery. "It plainly appeared" to him, that his "was to become a system of experimental philosophy that would embrace the whole surface of the globe."* Homely in exterior and manner, ungifted with the power of eloquent description, and averse to the labour of reducing his ideas to writing, few of his contemporaries would have dreamed of ranking William Smith as a man of genius: but posterity disregards externals, and judges men by their works; and I reverentially believe that in the truest sense of the term he well deserves the name. His clear-sighted sagacity, foreseeing the immediate application of local observations to world-wide areas, arose from a high combination of observing, inductive, and speculative powers—a combination of which the highest scientific genius is composed; his unswerving devotion, holding all other objects subservient to one great end, the heroic indifference with which he regarded all personal interests except in so far that they furthered it, his indomitable perseverance in the midst of difficulties and delays that hindered the production of his map of the English strata, all mark a man well worthy to be the first enunciator of a truth which in its consequences has opened to view a wide field for investigation that till his time lay utterly unapproachable. This grand and simple law, wedded to various branches of physical geology, already begins to "embrace the whole surface of the globe." This is what we are now doing. The "after ages" have already begun, when, as he predicted, we shall "get a tolerable description of the habitable world;" and on the further progress of this work of identification of strata, of mapping and of section making, depends at present most of the advancement of correct geological theory.

And here I would remark, that the results deducible from Smith's discovery afford another pregnant example of the economic application of purely theoretical principles, which in their first conception seemed but little connected with the furtherance of our material prosperity. In the expressive language of one

* Phillips's Memoirs of Wm. Smith, p. 10.

of my colleagues, "it is but the overflowings of science that thus enter into and animate industry"—a truth in the department of geology that I shall have occasion to illustrate in the sequel of this Lecture.

The right understanding of the law of superposition is not of value only to the man of science: it is important to every speculator in mines, to every landed proprietor who cares to understand the mineral value of his property; and the principles and greater laws pertaining to geological phenomena are now so distinctly understood, that there is no difficulty in imparting them to others. To draw an illustration from astronomy: we all know the truth of the revolutions of the planets and their satellites, of their general relations to the sun, of his relation to the fixed stars, of their motions in space, and of the dependence of their movements on the law of gravitation. Every well-informed schoolboy knows these things. We cannot all demonstrate them, but we believe in their demonstration; not alone that they do not contradict our experience, but principally by virtue of our faith in the men who have possessed a knowledge sufficiently high to solve the problems. Is it because geology as a science only numbers hundreds of years where astronomy numbers thousands, that beyond the pale of the student so much ignorance prevails regarding the simplest elementary principles and laws of the science, and that its cultivators are by many still looked upon as mere speculators; or, worse still, that others fancy themselves licensed to theorize without a particle of preliminary geological knowledge? Certainly not: true chemistry is but little older than geology; and no man fancies himself a chemist because he can *see* substances that enter into combination with each other. Not so with geology; without study, without training, without extended observation, and almost without reflection, many a man fancies himself qualified to decide on the nature and disposition of rocks (because they are before his eyes), whose decision is utterly worthless. If the leading features of astronomy are easy of comprehension, those of geology are more easily demonstrated, and but little less easy of understanding; the doctrines of superposition of strata, of succession of species in time, of disturbance of beds and consequent uncon-

formity, these and all other simple problems might (did there exist a race of qualified teachers) be made a part of every well-advanced schoolboy's education. Then, at all events, ignorant or mistaken men, misnamed practical, could not so readily delude the credulous or unwary into ruinous speculations: the iron-charged water of a spring, the colour of a rock, or the mere association of limestone and shale, might cease to induce explorations for coal among those who, hastening to acquire wealth, too often only precipitate their ruin; and I earnestly hope and believe, that not only by the aid of this School of Mines, but also by the more general spread of scientific education throughout the land, much may be done to prevent the frequent recurrence of so great a waste of energy and capital. To this particular end the more general diffusion of such authentic documents as the Government maps and sections will in time materially contribute, and much capital now wasted be skilfully applied, or diverted into other channels.

In Phillips's life of Smith several interesting notices are given of fruitless trials for coal in the Oxford clay, near Oxford and Wincanton. That at Wincanton was persevered in against the strong remonstrances of Smith. And here, instead of assuming a complete acquaintance in each of my audience of all the facts that bear on such cases (of which I shall cite other examples), you must permit me to explain one or two points that properly belong to a more advanced part of my course, but which it is now needful to point out for the full understanding of the subject.

I have alluded to the fact that the principal masses of strata were each in succession accumulated in sea bottoms; and these accumulations were composed of various sediments, just as at the present day quantities of mud, sand, and shingle are borne by rivers from the land, or torn from coasts and spread abroad on the floor of the ocean, to become the tombs of the creatures and plants that inhabit it. These beds have been, according to varying conditions, more or less consolidated, partially heaved above the waters, dislocated, invaded by igneous products, disintegrated, and denuded, their materials being often re-employed in the formation of later strata. And this process has been the course of nature through all traceable time. Hence it

follows that the rocks of continents and islands formed by such disturbances are necessarily of earlier date than the strata constructed from their wreck, and deposited in the surrounding seas; and the unconformity of one set of rocks to any other set will be proportionate to the amount of disturbance of the strata so upheaved, denuded, and often deeply depressed beneath newer accumulations. This unconformity was, as early as 1669, alluded to by Steno in his Prodromus, in which, by a series of rude diagrams, he sought to prove that the "country of Etruria hath been twice fluid, twice plane and dry, and twice scabrous and craggy." Strachey also had a faint knowledge of this fact as exhibited in his diagrams of the unconformity of the coal measures and new red sandstone of Somersetshire.* Our illustrious Hutton was, however, the first geologist who clearly expounded the laws of unconformity, and proved their universal application.

How, then, do these truths bear on the question, when, as in the instance recorded by Smith, sinkings were begun in the Oxford clay, the dark coal measure colour of which deceived the speculators and prompted the experiment? In the first place it is perfectly known, that excepting in the coal measures no coal occurs in any other formation in this and the surrounding districts. The sinkers knew this, for when they reached the oolitic limestones they abandoned the attempt. At what depth, then, had they persevered, might the true coal measures have been found? There is little reason to doubt that it would have been necessary to have sunk through oolitic and other rocks, (too thick to permit of such a speculation being profitable,) at the very least from 1,500 to 1,800 feet.

But even then there would have been no certainty of reaching the coal measures, for the newer rocks rest unconformably upon the older strata, and it is not improbable that owing to known disturbances other beds beneath the coal may rise towards their base at the point beneath the shaft.

It is forty years since this incident occurred. There are now sparsely scattered throughout England mining engineers of high

* Philosophical Transactions, vol. 33. p. 395.

attainments, well versed in the principles of geology; and the science is reaching a point when problems in economics may be solved far more obscure than those that tasked the knowledge of Smith; but you must not therefore suppose, that, as a general rule, many of our proprietors and speculators are guided by a higher knowledge than then prevailed. Such is not the case. Throughout the length and breadth of the land, down to this very day, equally fruitless and still more absurd undertakings are constantly being entered upon. I shall cite several other instances.

I have been informed that near Tiverton, in Devonshire, many years ago, a shaft was sunk in the shales of the mill-stone grit, an unprofitable set of beds at the base of the coal measures. As might have been foretold, nothing was found, till one Sunday, when the population were safely housed in church, some boys emptied a coal-scuttle into the pit, and on the top threw in part of the extracted rubbish. Great was the joy on Monday morning when the miners brought up the coal: it was declared to be "as good as Newcastle" (which indeed it was), and all the parish bells were set a-ringing!

On Chard Common, near Lyme Regis, they bored in the lias for coal, at an expense of several thousand pounds. The deception was fostered by the accident of passing through, not a *bed* but a *piece* of lignite. Numerous lias fossils were turned out, which of themselves ought at once to have decided the question, even without a broader knowledge of the geological structure of the country.

A similar trial took place at Kingsthorp, near Northampton, where a shaft was sunk through the lower oolite and lias, at an expenditure of near 30,000*l*. The adventurers desisted when they reached the new red sandstone. Many similar instances might be multiplied.

In the coal-field of the Forest of Dean the carboniferous limestone shale lies 1,000 feet beneath the lowest bed of coal. Nevertheless, in Herefordshire, a person, more confident than sagacious, first built his engine-house, and sheds to receive the produce, and then boldly sunk a shaft in these beds in search of coal, where it could not by possibility exist. In future lec-

tures I shall show that the coal measures once extended above this area, but the conditions never obtained by which one bed of coal could have been formed either in the beds explored, or in the old red sandstone on which they rest. At the very moment I now write I have received a letter from Mr. Aveline, one of the geologists of the survey, in which he says: "I have a narrow slip of coal measures running between the Permian, the new red beds, and the old red sandstone that you saw at Bewdley. A person found out the only place where the coal is well shown, and sunk a pit, but finding the coal worthless, *he has gone a little way off on the old red sandstone*, where he is sinking after the most approved manner, bricking his shaft round. He is going through some very hard sandstone." In this case the true explanation, of course gratuitously offered, was disregarded, and the last report announced by the "practical men" was, that they were on the very verge of discovering coal.

Observe in the vertical column, and in this horizontal section, the geological position of the lower silurian shales, utterly barren of coal, and sunk thousands upon thousands of feet beneath the coal measures, carboniferous limestone, and old red sandstone.* They are often black, and carbonaceous-looking, and their oozing springs are sometimes discoloured and scummy by the presence of oxide of iron, and other impurities derived in the passage of the water through the rocks. But coal measure shales are also frequently black, carbonaceous, and charged with numerous beds of ironstone, which, discolouring the springs, produce the red water (dwr goch) of the Welsh miner. By a mistaken application of the principle, that like causes produce like effects, the empirical miner sets to work, and the black slates of the counties of Pembroke, Radnor, and Caermarthen, —of Montgomery, Merioneth, and Caernarvon,—near Trefgarn, Caermarthen, Builth, Llanidloes, in Lleyn, and at Caernarvon, —are dotted with shafts, borings, and levels, sunk or driven in delusive searches for coal. While in progress, the cry still is, "the indications are good, go a little deeper;" and the pit, the

* Alluding to diagrams on the wall.

disappointment, and the ruin, often deepen together, till, abandoned in despair, the speculator is left to console himself with the parting assurance, "We are not to blame;—had you only gone a little deeper." Long after, when the wandering geologist visits such spots, he is informed that the miners actually found coal, but were bribed to hush it up by coal owners jealous of their markets.

I do not wish to imply that the men who advise such undertakings generally wish to deceive. Ignorance on both sides lies at the base of the enterprise. But on that very account, I repeat, that even a slender amount of science infused into the general education of the country would strongly tend to prevent the unceasing recurrence of such ruinous absurdities. The truly practical man,—the scientific mining engineer,—reasons and advises on very different principles. He is conversant with geological maps and sections; his experienced eye distinguishes the geological relations of the deep and wide-spreading strata of which a country is composed, and as a rule, he knows the utmost limits of the ground where it is safe to adventure; and, further, if he add to this a general knowledge of the organic forms that characterize these formations, a glance will tell him (however black the shale, or ferruginous the water,) that rocks containing graptolites, trilobites, lingulæ, and pentameri, were formed untold ages before the commencement of our carboniferous epoch.

It is foreign to my present object to trace the career of Smith in the application of his principles to agriculture, canal engineering, the interception of springs, opening of quarries, or the detailed determination of the position of coal bearing strata, concealed by overlying masses of new red sandstone. The immediate scientific results of his work* you see in this diagram, which exhibits his enlarged and corrected ideas of superposition, as understood by him, in the year 1816, and by this map, published in the previous year. This was the first geological map of England, or, indeed, of any kingdom, ever

* Smith's Column and Map.

produced,—a work in those days of extreme difficulty, when we consider that almost all the data were new and collected by himself; and that no large uniform topographical maps of authority then existed on which to depict them. Though propositions were made to the Government of the day, it yielded him no aid; the arduous work, wonderful in its kind, was accomplished by his own individual efforts; and it was not till many years later that, recognizing the national importance of a truly accurate survey on an adequate scale, Government established, under the direction of Sir Henry De la Beche, a geological survey of Great Britain in connexion with the Board of Ordnance. The survey then established, and since extended to Ireland, is now in full operation under the department of Works: the local direction for Ireland has been entrusted to Mr. Beete Jukes; the survey of England and Scotland is entrusted to my care, both being subject to the control of Sir Henry De la Beche as Director General. The basis of the survey is the Ordnance maps. A specimen of a portion of the work executed in England and Wales hangs on the wall, and when a sufficient area has been topographically surveyed, and other needful arrangements made, the survey will commence operations in Scotland.

On this extended scale, with a correct topographical basis to work upon, it is evident that a skilful geologist can lay down a multitude of facts in a style that, both for accuracy of general outline, and minuteness of detail, was formerly undreamed of by geologists; and I think I may be permitted to say, that great has been the benefit accruing, and yet greater will accrue, from this work, alike scientifically and economically. The boundaries of every formation, and of each of their subdivisions, of every igneous mass, intrusive or bedded, with all their accompanying intricacies of interstratified slates and volcanic ashes, the run of workable slates, of beds of freestone, limestone, and gypsum, every dislocation, metalliferous lode, and outcrop of coal, are traced with all that minuteness of detail admissable on this comparatively extended scale. These are accompanied by enlarged illustrative longitudinal and vertical sections, drawn in *true proportion*. As an instance

of their value, I would remind you that the broadest and deepest coal-field in Great Britain is that of South Wales. After the publication of the maps of that country, landowners, coal proprietors, coal viewers, and mining engineers, all acknowledged their importance; and I had the satisfaction of hearing the observation of a gentleman well versed in mining and scientific geology, "that the publication of the Government maps had placed them thirty years in advance of what they were before." I will be excused from the imputation of attempted self-laudation when I state, that that district was completed principally by Sir Henry De la Beche and Mr. Logan before my connexion with the survey began.

I shall give one other example of the application of geological principles to the solving of a question which will one day be of great economic importance: it is drawn from the work of the geological survey now in progress in the centre of England. As our sections in that country are still incomplete, I can only at present explain the principles on which our conclusions depend by means of diagramatic sections.

Underneath the true new red sandstone on the borders of Nottinghamshire and Derbyshire, is a strip of country noticed by Smith, but first fully described by Professor Sedgwick. He divided its rocks into magnesian limestone, and lower new red sandstone.* These rest unconformably on the coal measures, which they follow in the order of superposition. Owing to differences in lithological character, and the absence of the limestone, the Staffordshire, Warwickshire, and Shropshire coal-fields were long considered as unsurrounded by these beds. The upper new red sandstone was supposed to rest directly on the coal measures. By degrees, however, their existence in sundry places was noticed or surmised, and now on some of the smaller published maps indications of their existence may be found, both where they are, and where they are not. With a difference they are so exceedingly like the new red sandstone, that they have for the most part been confounded with it, at least

* The Pontefract rock, of Smith.

by almost all those engaged in the working of mines; and again, in some respects their mineral character here and there strongly resembles certain red portions of the coal measures; They are, therefore, in most maps sometimes incorrectly delineated, but distinguished from,—and sometimes erroneously included in, the coal measures, or new red sandstone, as the case may be.

It chanced, however, last year, that by dint of constant practice and study in the field, my colleague, Mr. Hull, discovered a key to the separation of these rocks from any others of the district; and the progress of the mapping of the country has shown, that everywhere, except in accidental cases, they rest unconformably on the coal measures, and that the new red sandstone is unconformable on both.

Now, for reasons that I cannot at present enter upon, it is known to geologists that concealed treasures of coal probably underlie the larger portion of the great area of new red sandstone that surrounds the coal-fields of central England. Already in great part of South Staffordshire most of the best beds of ironstone are being rapidly exhausted; and in great part of the district "the thick coal" has been extracted, or the workings are so drowned by water, in consequence of the faults being worked through by gate-roads, that its drainage is next to impossible. The day will surely come when this and other coal-fields will be worked out; and the question will then arise, at what depths beneath the unconformable covering that shrouds them, will coal-bearing strata be found in various localities? This is an important problem, which the work we are now engaged upon will go far to solve.

By means of numerous observations of the dip of strata, and the construction of sections on a true scale, it is often possible to determine the thickness of any special mass of rocks. Within a given area, where, therefore, is the new red sandstone likely to have the smallest thickness? or, in other words, where can we predict that the concealed coal measures rise nearest to the surface?

In this diagram you will observe that the lower new red sandstone, or Permian strata, rise against the coal-fields on the east

and west, and that the whole is overlaid by the upper new red sandstone.* It is therefore to be expected, that in this district, the lower new red sandstone, strata intervene between the upper new red sandstone and coal measures throughout. This suspicion is confirmed by the circumstance, that within the new red sandstone area surrounding the central coal-fields of England, many miles removed from these fields, the beds that elsewhere rest directly on the coal measures are brought to the surface by faults.

If the estimates of thickness be correct, then no wise man would sink in this area on the new red marl, because, before he could reach the coal measures, he would have to penetrate the aggregate thickness of three formations, viz., new red marl, upper new red sandstone, and the lower new red sandstone or Permian.

To the unpractised eye, these last seem ordinary new red sandstone. In this area they were confounded with it. But a rigid geological examination has shown that they belong to a lower set of beds, and that faults at certain points raise them to the surface; and these may be proper places in which to sink in the hope of finding coal, because the concealed coal measures must also be raised nearer the surface by the faults, and therefore in the search, we escape many hundreds of feet of rock that elsewhere overlie the strata to be sunk in.

There is yet another point of interest in connexion with this subject. I have stated, that the new red sandstone proper rests unconformably on the lower new red strata. It therefore often happens, that overlapping the latter it rests directly on the coal measures. The result is, that at a distance from the carboniferous strata, it is possible to estimate the probabilities as to whether in sinking through new red sandstone, we might reach the coal measures without the intervention of thick masses of lower new red or Permian strata.

These are questions that daily assume a higher importance. The attention of proprietors and miners already begins to be

* Illustrated by a diagram of the disposition of the strata round the South Staffordshire and Coalbrook Dale Coal-fields.

directed to them, hitherto in general without much effect, chiefly for want of accurate geological information. The value of land will be materially affected in certain districts by the information yielded by such maps and sections.

If you compare a distorted section with one across the same country drawn on a true scale, you will readily perceive one of the causes of the indefinite ideas often entertained on such subjects. In one the distances are diminished, the heights absurdly exaggerated, and the disposition of the strata therefore necessarily falsified; in the other, a true corresponding scale for distance and height being adopted, the lay of the beds as they actually occur in nature is obtained, and the conclusions arrived at are precise and definite. On me devolves the responsibility of instructing the pupils in the School of Mines in the methods by which accurate geological maps and sections are constructed; and it will be my duty to do so, not only in the lecture room, but also through the medium of the districts in progress on the geological survey, to convey practical instruction in field work to those of our mining or engineering students to whom such knowledge may be indispensable.

It would be easy to show many other applications of geology to practical purposes, as, for instance, in the construction of roads, and the selection of material for macadamising, in the engineering of canals by leading them over naturally tenacious bottoms and the avoidance of porous formations, in the selection of minor deviations of lines of railway with reference to cuttings and tunnels, and also in the sinking of shafts. An instructive instance connected with shaft sinking came under the notice of Mr. Bristow of the geological survey. On the Ridgway tunnel a shaft was sunk through 80 feet of sand, which rendered it necessary to brick the sides, whereas a few feet further in either direction would have carried the shaft safely through the chalk. The sinkers had, in fact, chanced to sink in one of those holes in the chalk known to geologists by the name of "pipes." These are always of small diameter, and probably originated in the percolation of rain water, the carbonic acid having carried off the lime in solution; they afterwards became filled with foreign substances, *in* which, in this instance, they sunk.

A knowledge of this simple fact would have prevented the blunder.

The agricultural applications of geology have been ably treated by Mr. Trimmer; and its bearings on large supplies of water to towns are beginning to be universally recognized. The country around and beneath London affords a tempting field for enlarging on this subject, but at present I shall rather refer to the construction of the artesian well at Grenelle, principally because it was undertaken and executed on data and principles purely geological.

In earlier times the phenomena of springs gave rise to much discussion. While some considered that they originated in great subterranean reservoirs, others asserted that they were due to the percolation of sea-water which flowed upwards by subterranean cavities, losing its saltness in the passage. More than a hundred years ago, Valisnieri partly explained their dependence on the fall of rain, and the nature and arrangement of the strata through which the water percolates. Since his day, the theory of springs has by degrees come to be well understood, and from the time of Smith, by strict attention to geological data, it has been possible to estimate with almost absolute certainty the results of sinkings in search of underground water in numerous localities.

Rocks are of many degrees of hardness, and variously disposed. Thus, for instance, granite and its igneous allies, are but slightly porous, and it is only through joints and cracks, generally of no great depth, and having little intercommunication, that the surface water can penetrate; and thus the subterranean oozings are isolated, so that generally no great body of underground water is anywhere collected, and numerous feeble springs rise here and there to the surface. But it is different with many of the stratified rocks, which not only by a multiplicity of joints, but also from their extreme porosity, and the sloping disposition of the beds, are often perfectly adapted to the conduction, and partial retention, of large bodies of water, at depths varying with the disposition of the strata.

The nature of artesian wells is simple. If I take a bent tube and pour therein any quantity of water, it will maintain a corre-

sponding level on either side; and if I insert another tube shorter than the curved arms, (we shall suppose at the lowest point of the curve,) then, by virtue of a law of hydrostatic pressure, the water will rise in the inserted tube, an equal amount being displaced in the curved arms on either side. There it will rest. But if a constant supply be yielded to one or both of the openings of the curved reservoir, then the water will overflow at the mouth of the central inserted tube, which thus represents the boring of an artesian well.

The strata around Paris are in a general way very similar to those forming and surrounding the London basin, (as it is often termed,) with which many of you are familiar. Its highest members are composed of tertiary strata of sand and calcareous sandstone, beneath which are beds of mottled clay. The chalk on which this lies is 1,477 feet thick, resting on 150 feet of green sand, which in its turn lies on the gault. This last is for the most part composed of clay, and nearly impermeable to water. The whole over a width of many miles is arranged in the form of what geologists term a basin, that is to say, the strata from their outcrops have a tendency to slope towards a general centre, where for a space they lie more or less horizontally.

On the margin of the basin, strata of green sand and gault rise to the surface at heights in many places approaching to 330 feet above the sea, Grenelle being only about 100 feet above that level. Geologists knew that the water which fell on these strata at their outcrop would of necessity percolate in the direction of the inclination of the beds, so that, at the lower points of the curvature, a great body of water must exist, confined as it were in a sponge, and unable to escape below, because of the impermeable quality of the beds on which the porous strata rest. This deep-seated reservoir being tapped by boring, the water would rise to the surface in the manner I have explained.

In 1832 the municipal corporation of Paris, impressed with the sanitary necessity of further supplies of water, voted 18,000 francs for the construction of three artesian wells—a sum so ridiculously small that the project was immediately abandoned. M. Mulot, however, one of their engineers, having previously

sunk in the chalk at Suresne, at Chartres, and at Laon, to the depth of 1,082 feet, proved that it would be necessary to bore completely through that formation to ensure a sufficient supply. This conclusion, based on strict geological reasoning, was confirmed by M. M. Arago and Walferdin, and in November 1833 the work was begun. With infinite energy, skill, and perseverance, M. Mulot carried it on, overcoming every opposition, physical and moral; for he had not only to conquer those natural difficulties that beset so unexampled an undertaking, but he had also to contend with municipal parsimony, that shrank from the continuance of supplying funds for a project based on purely theoretical grounds. When he reached the depth of 1,640 feet, at an expense of 263,000 francs, they stopped these supplies; but so great was the faith of M. Mulot in the correctness of the principle involved, that he determined to continue the work at his own charges. On the 26th of February 1841, the borer suddenly fell several yards, and immediately, from a depth of 1,800 feet, there sprang from the orifice a huge column of water, cold at first but warm afterwards. It now steadily yields more than 740,000 gallons per day. At the first burst the supply was greater.*

These are some of the subjects to which geology lends its aid in promoting our material prosperity, comfort, and health. But its bearings in many other directions extend far and wide. Physical geography, for example, is in reality a branch of geology, for the present forms of sea and land are but the result of all the geological changes to which our globe has been subject, and existing forms of vegetable and animal life are to the present world what the fossil forms in the rocks (and many more unpreserved, or that may never be disentombed,) were to the scenery of the lost continents and islands of bypast epochs. Viewed in this light, geology connects itself with the more graceful arts that at once adorn and elevate society, and that quite independently of the beautiful mineral substances yielded by the rocks for purposes of art. It becomes of value to the

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* See Le Puits Artésien de Grenelle, par M. Rey. Paris, 1843.

artist, for it cannot be quite unimportant to him that he should be ignorant of the origin of the infinite diversities of scenery, of the great operations that have given distinctive features to every plain, and hill, and mountain crag. In many a depicted scene, however skilfully coloured, the geologist who has an eye for art sometimes detects improbable forms or combinations. The sculptor and the historical painter may not safely be ignorant of anatomy, and on the same principle it cannot be a matter of small moment, that, merely copying externals, the landscape painter should be utterly ignorant of the inner anatomy of the scene; for I cannot but believe, that a certain knowledge of this structure will go far to give the impress of a vivid reality to the landscape he delineates, when, abhorring conventional forms of rock and mountain, he, in his compositions, bearing in mind the actual value and relation of all the parts of a landscape as composed by nature, transfers to his canvas the truthful impressions of a well stored and cultivated mind. It is this perfect truthfulness that often lends so exquisite a charm to the works of the greatest English landscape painters of modern times, whose mountains and rocks are so true that the geologist can often pronounce their very nature and their names.

I must now close. In succeeding Lectures it will be one of my aims to inculcate that a sound knowledge of theory is indispensable towards all the applications of geology, whether economic or otherwise. Let not any man consider that when he has mastered the few facts that may be immediately turned to account in money getting, that his geological education is complete. The men who first educed all our great results were mainly actuated by the love of truth alone; and the applications are an accidental fruit of that love. On every possible ground it is, therefore, worse than impolitic to undervalue any truly philosophical work of the geologist, whether it be shown in the unravelment of geological intricacies in the mountains, or in abstract studies in the closet. As a point of conscience actuated by these principles, it has been the aim of those engaged on the geological survey to carry accuracy of scientific detail to the extremest possible limit; and (independently of any immediate benefit to science and to the owners of the soil) who can predict

what may yet arise to further the arts of peace from such labours, even in districts apparently the most unprofitable? Let no geologist, therefore, be discouraged because of the sneering cry *cui bono*. The true man of science will not heed it; and hitherto geologists have pursued their ends unscared.

No people has produced so many men eminent in geology as the British Isles. Though not the birth-place of geology, it is here that it has been principally fostered and reared to its present goodly stature, within the memory of many yet living. Of the illustrious men who aided in this work some have passed away, but others still remain among us; and difficult as it may be to follow in the footsteps or to emulate the "large utterance" of these early giants, I earnestly hope, albeit the signs are few and meagre, that a race may yet spring up not unworthy to be their successors. The links that bind primeval time to our own have to be sought out,—the history of a world has to be unravelled. The alphabet has been discovered, and some of the inscriptions graven on the rocks are deciphered; but many readings are wanting, many passages obscure. The time is still early, the subject is but opening to view, and its revelations are boundless. Hitherto there has been a wonderful unanimity of purpose among all true cultivators of geology. The advance of geology, through the friendly co-operation of its votaries, has known no pause since the decline of the Huttonian and Wernerian controversy. The physical structure of our country is one cause of this rapid progress, but the earnest character of the men who investigated that country is another secret of the strength that has so rapidly urged the science onwards; and I earnestly trust and believe that that strength will know no decay while the rising cultivators of geology continue worthily to follow the bright example set by their great predecessors.

On the Value of an Extended Knowledge of Mineralogy and the Processes of Mining. (*Being the Introductory Lecture to the Course of Mineralogy and Mining.*)

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Πολλαὶ τέχναι ἐν ἀνθρώποις εἰσὶν ἐκ τῶν ἐμπειριῶν ἐμπείρως εὑρημέναι· ἐμπειρία μὲν γὰρ ποιεῖ τὸν αἰῶνα ἡμῶν πορεύεσθαι κατὰ τέχνην, ἀπειρία δὲ κατὰ τύχην.—Plat. Gorg. (*Polus.*)

There are many arts among mankind which have been invented by the experienced, through the means of experience: for whilst experience causes our age to advance by the principles of art, a want of it leaves us dependent on chance.

HAVING been honoured with the charge of opening in this Institution a course of instruction on Mineralogy and on Mining, I deem it desirable in the outset to define the limits of these distinct although kindred subjects, and to point out the directions in which they dovetail into the other branches of applied science as treated by my colleagues. The technical character of the education to be imparted here will be the beacon which I shall endeavour to keep in view, that I may avoid being drifted by the current of thought too far into the wide expanse of general considerations, where in connexion with those studies so much that is beautiful and useful in ordinary life has already been acquired, and so much still remains to be discovered; but where in the meanwhile we might wander wide of the desired path. This discourse will therefore deal almost entirely with matters of practical application; and a number of examples which have been brought under my own observation during a few years past will be adduced in support

of the proposition—that *an extended knowledge of mineralogy and the processes of mining are essential to those interested or engaged in mines.*

In the commencement of an inquiry into the infinite variety of objects surrounding us in the natural world, presented, it would appear, for the purpose of inducing the most attractive and holy exercise of our observing and reasoning powers, it is obvious that three principal assemblages are to be discriminated. These divisions are the animal and vegetable kingdoms, characterized by organic structure, and the wondrous phenomena of life; and the inorganic or mineral kingdom, comprising that far greater proportion of the materials of the planet in which no traces of organic structure are observable. This last assemblage of objects has been generally understood to form the province of mineralogy, which thus in its most extended sense would include all the aëriform and gaseous bodies occurring in nature, and could hardly venture to exclude the multifarious substances produced under similar chemical laws by the agency of man.

But since, amid the daily increasing accumulation of new and unexpected combinations, the domain of the inorganic kingdom appears unlimited, and many of its phenomena must be investigated by special departments of science, it becomes necessary to draw a boundary line around that portion of it which is to be embraced in modern mineralogy; and where we can find no logical distinction between the actual products of similar bodies and similar laws, as seen in nature or in art, we must, for the sake of convenience and utility, rest our criterion of separation upon the different conditions of their origin.

Under this point of view mineralogy has for its object the consideration of the natural inorganic materials of our globe, fluid and solid; the physical phenomena which they present, their chemical constitution, their modes of occurrence, the methods by which they are distinguishable from each other, their classification, and the uses to which they may be made subservient.

Now it is evident that as the characters of minerals are dependent partly on their form, partly on their chemical and partly on their physical properties, mineralogy must be based upon geometry, chemistry, and natural philosophy; and the

history of the science affords the best proof that no branch of knowledge can rise towards perfection till the conterminous sciences have, after due cultivation, been brought forward to aid in its development. The student should therefore previously acquire a certain acquaintance with these auxiliaries; and it is for this reason that the lectures on chemistry and physics have been so arranged as to precede the more compound subjects on which we are now about to commence.

It may at first sight appear trivial and unnecessary to insist on the definition and objects of mineralogy; but, in addition to the importance of a clear understanding of the purport of any branch of education, there are in the present case special reasons for adopting such a course. This science has in Britain, for many years past, been cultivated by so small a number of investigators, that by the public at large it has been almost lost sight of, and is not unfrequently confounded with chemistry, geology, or metallurgy. Nay, there are not wanting among scientific men those who assert, that as a mere department of chemistry it can hold no independent place, nor offer a foundation for a special course of study. The above definition, however, may aid in fixing its true position, and will show, that whilst we contend with such opinions on the one hand, we would oppose on the other the vain struggles of those who have endeavoured to disconnect the science from that chemical aid which has so much advanced its progress and heightened its interest.

The prime and grand interest attached to our studies of the products of the earth is to be found in the fact that the mineral properties of different lands, in conjunction with their geographical features, have determined the distribution, the physical and social character, and the well-being of the various races of man. Whether we examine the vestiges left by the peoples of gray antiquity, or study the modifications produced in branches of the same race located in regions of different aspect, or inquire into the origin of the chief seats of modern civilization, we shall be assured that most of these phenomena are dependent immediately, or through the medium of vegetation, on mineral produce, and the particular conditions under which it can be made available to human convenience.

In the remains of ancient Egypt we learn how a stupendous architecture arose by the aid of the soft yet massive sandstones piled by nature on the banks of the Nile, and how monolith statues and obelisks were suggested by the presence of a syenite capable of taking a high polish, and admitting of the sharpest intaglio tooling. In Attica the marble of Pentelicus and the silver of Laurion combined to develope that high state of art which, exemplified in the Parthenon and the sculptures of Phidias, has never since been equalled; whilst the abrupt limestone ravines of Lycia and Arabia Petræa gave rise to a description of architecture peculiar to itself.

As examples of the second point, call to mind the different occupation and character of the dwellers in the Spanish peninsula,—the active mining and mercantile population of Gallicia, Asturia, and the Basques on one hand, the indolent Castilian and Portuguese on the other.* Or compare the torpid millions of the Slavic race in the plains of Russia with their industrious relatives and co-religionists in Servia and Bulgaria.†

Lastly, in furtherance of the third inquiry, we need only to examine the beautiful population map of the British Islands by Petermann, which shows at a glance that besides the conditions requisite for the purposes of shipping, it is coal and iron and lead and copper that mainly influence the increase of our towns. Nor can we omit to refer to the amazing process by which the discovery of gold is at this day pouring a new tide of population over parts of Siberia, to Western America, and to the Antipodes.‡

Such general views are, however, somewhat foreign to my purpose; for the main question which lies before me is the importance of mineralogical knowledge to those engaged in technical avocations. Enormous as is the interest at stake in

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* Le Play, Ann. des Mines, 1834.

† C. Weerth, "Die Entwickelung der Menschenracen durch Einwirkungen von aussen." Lemgo, 1842.

‡ Virlet, "Coup d'œil statistique sur la Metallurgie dans ses Rapports avec l'Industrie, la Civilisation, et la Richesse des Peuples." 1837. Ami Boué, "Der ganze Zweck und der hohe Nutzen der Geologie." Wien, 1851.

connexion with this science, it is obvious that a more or less profound acquaintance with its facts must be productive of considerable differences in the progressive development of the national wealth. It is surely patent to all that the miner ought to be thoroughly acquainted with the nature of those substances which it is his daily task to seek in the recesses of the earth, as well as with those which exert a favourable or a pernicious influence either on the abundance or quality of the objects of his search. No less should he be prepared to recognise those which, although unusual in the spot where he has commenced his career, may be thrown in his way either in another part of the same vein, or in neighbouring veins of the same district, or even in other lands, to which, by the varying demands for mining skill, he may so probably at some time be transplanted.

Supposing even that our miner had perfected himself in a science requiring far more close application to books and in-door study; supposing that he were an expert chemist, I venture to assert, that although in many cases highly serviceable to him, this rare acquisition would not make amends for an ignorance of mineralogy. Were he, each time that he required to know the nature of a substance, obliged to enter upon its chemical analysis, his days and years would be passed in endless labours often repeated and sometimes fruitless. If we concede that after twice or thrice analysing the same ore, for example, he were to recognise it the fourth time by some less laborious test, we allow, in other words, that he has acquired a mineralogical knowledge of that single substance: and thus we arrive at the conclusion, that the methods of mineralogy are those which a man must employ, if, in relation to the natural inorganic bodies, he desire to reap the advantages offered him by previous investigations.

There exists, it is true, in practice a source of difficulty which has probably gone far to prevent the spread of our science. Whilst many of the more abundant and valuable productions of the mineral kingdom are met with in such a state of impurity from mechanical aggregation and admixtures, that the particular minerals of which they are composed are not separable by physical means, others occur only in an amorphous or irregularly shaped condition. Now scientific mineralogy bases its descrip-

tions on the most perfect individuals, or crystals, of each species, bodies which are comparatively rare; and treats with but little respect those which are never crystallised, and of which the distinguishing characters are less definite. It stands to reason that in an Institution of a practical tendency the strictness of such rules must be relaxed, and that greater weight must be attached to those substances, chemically impure though they may be, which are abundantly yielded by our mines and quarries, and yet scarcely constitute true mineralogical species.

We shall thus, for example, study the characters of the pure carbonate of iron in the crystals occasionally lining the cavities of our lodes, in the masses which exert so powerful an influence on the industry of Nassau and the Austrian Alps, and again in those indefinite mixtures which as nodules and continuous beds have, from their geological position and abundance, contributed in a high degree to raise Great Britain to her present pinnacle of manufacturing power.

But the cause of such a preference in mineralogical works is at once evident, on comparison of the objects described with those of the other classificatory sciences.

In the animal and vegetable kingdoms the naturalist traces, in successive groups of animals and plants, a descending scale of lower and lower organization, till at last, in the most rudimentary forms of life, individuality is lost in an assemblage; yet down to this point each species presents none but forms complete in themselves, and almost unvarying. In the mineral kingdom, on the other hand, we are obliged to seek out for description the most perfect specimen, because it is not a succession of species, but the same species which offers a never-ending diversity of aspect. The mineral species may indeed occur in every state of development, from the symmetrical crystal, composed of definite constituents, passing through every grade of incompleteness of form or admixture with foreign substances, till we reach the lowest step of the scale, where the individual is so merged in the mass that form is destroyed, and the other characteristics are no longer discernible to the sense. How striking is the parallel in human societies, where the development of mind and resources unmistakeably accompanies such arrangements as lead to the

self-reliance and importance of the individual, whilst as surely the crippled freedom of action caused by merging individuality in the crowd is attended by deterioration and destruction of all healthful prominences of character!

But besides the miner, there are hundreds and thousands amongst us whose pursuits, bearing on the practical purposes of life, render a knowledge of mineralogy an element of success. The geologist, the engineer, and the architect must have recourse to mineralogy to gain acquaintance with many of the materials which they employ; nor, even if they possessed unlimited time and means for the acquisition of chemical analyses, could they afford to overlook the physical properties which are often chiefly instrumental in fitting those substances to their several applications. The agriculturist, if he wish to modify and improve the condition of his soils, must become familiar with the appearance and qualities of the marls, limestone, gypsum, phosphorite, and other minerals, which are now beginning to exert a remarkable influence on his art. The antiquary, without a knowledge of the stones from which the ancient inhabitants of the earth sculptured their idols, reared their temples, or fashioned their rude implements, and of the ores from which they produced their metals and alloys, can draw no sound conclusions as to the comparative civilisation of distant epochs, nor guard himself from the blunders consequent on faulty observation or crude description. Who, again, that is not insensible to the varied beauties of the brilliant gem, would hesitate to prefer to determine its nature by the methods of mineralogy instead of entrusting it to the chemist, who, with ruthless hand and devouring acids, must destroy its substance ere he can pronounce upon its character?

Other and numerous mineral productions there are for a decision on whose value we are dependent on the aid of analysis. Among the irregularly mingled bodies to which I have before alluded are many which, like the iron ores lately discovered in the oolitic formation, can only be determined as to their importance by accurate assay. Few among the crowds who at the late Industrial Exhibition swept by the series of iron ores brought together from all parts of Britain by Mr. Blackwell, could have prophesied that the collection of half a dozen of those

sombre stones would give rise within a few months to an active industry, which bids fair to develope a new phase in the gigantic phenomenon of the British iron trade. An example, this, of the mutual dependence and assistance of three sister sciences, where geological reasoning had to point out the tract in which a given formation was to be found, mineralogical observation to discover the actual deposit, and chemical analysis to determine the value of the ore.

The mining districts of Great Britain are so utterly destitute of the means of mineralogical education, whether in schools or suitable collections, that it need be no source of wonder to find the most intelligent miner acquainted only with some two or three of the substances, which in the routine of his employment have been brought prominently before him, and often neglecting others from ignorance of their nature, or dangerously confounding things which are totally distinct from each other. It is matter of history that the copper ores of Cornwall were recognised as useful only at a comparatively late date, the miners having concentrated all their attention upon the tin with which that county was so plentifully supplied. More wonderful does it appear, that even at the commencement of the last century, when the yellow ore or pyrites had been long appreciated, the far more valuable redruthite, or sulphide of copper, was thrown as worthless rubbish over the cliffs of St. Just into the Atlantic; and Pryce informs us, that "many thousand pounds worth of the rich black ore, or oxide of copper, was washed into the rivers and discharged into the North Sea from the old Pool mine."*

These might be considered as the errors of a past age, but we may recollect that they occurred at a time when the value of the same substances was understood in other countries; and by mere accidental rencontres similar cases are still not unfrequently brought to our notice.

During a visit, three or four years since, to a mine which was supported chiefly by raising blende, the sulphide of zinc, my attention was attracted by a lump of white mineral lying on the window-sill of the office, a single glance at which was sufficient

* Pryce, Mineralogia Cornubiensis, 1778.

for recognition; and I put to the agent a few questions regarding its nature and occurrence. He replied that it was nothing but "spar", and that in working a particular part of the lode they had met with many tons of it, which, however, had been all, except this accidentally preserved specimen, irretrievably mixed with the rubbish heaps. The surprise of my informant was not small, when he learned that the so-called "spar", confounded by him with quartz, was calamine, an ore containing in its pure state above 60 per cent. of oxide of zinc. Not to leave the same metal and its ores, which put on a great variety of characters, I have known zinc blende taken for lead ore, and honoured with the erection of a smelting furnace, when, to the chagrin of the manager, the volatile metal flew away up the chimney, leaving only disappointment and loss behind. Again, from a faint resemblance which some of the varieties bear to certain iron ores, a resemblance which would at once disappear before accurate observation, a considerable quantity was bought, not long since, by one of the greatest iron-masters in this country. It was carried to the furnaces, duly mingled with fuel and flux, and after a strenuous effort had been made to get it to yield iron, it all, as the proprietor naïvely remarked, "went off in smoke."

Blunders of this kind are more excusable when made in regard to some of the minerals of comparatively rare occurrence. An active agent of my acquaintance, a man of high character, was requested by a couple of his friends, who gave themselves credit for uncommon sagacity, to join them in forming a company to work a deposit of an unusual ore which they had lately found. Already they had referred it, for corroboration of their opinion, to a person at Birmingham styling himself a mineral chemist, whose report set forth that the specimen shown him was, as the others had suspected, an ore of molybdenum, and that it was worth 8*l.* per ton. This was sufficient to induce the agent to join the discoverers in a journey to the place in question, and at the head of a remote valley, embosomed among the rugged hills of Cambria, he was gratified with the view of such a mass of the same substance that it was evident that thousands of tons might be quarried at a mere nominal price. Specimens were broken, the party returned to consider the preliminaries of their adven-

ture, and it was agreed that the mineral corresponded pretty nearly with the description of sulphuret of molybdenum in some book, which was at hand. Still, the more cautious manager feared that the prospect was too bright to be real, and without consulting the others, expended a fee in sending for a good analysis to a scientific chemist in London. The result was, that the substance in question proved to be a shining, black, slate-clay, not applicable to any use, except perhaps to make bricks.

Within a gunshot of the place where the above-mentioned agent related this anecdote, the appearance of some rather ferruginous slate rock attracted the attention of a party of credulous speculators, who believing they had discovered a rich iron ore, actually built a blast furnace, erected the necessary machinery, and continued for some time to carry out their vain attempt, deluded by the fraudulent practices of the workmen. As might, however, have been predicted, the undertaking soon ended in abandonment and ruin.

In other mining districts I have known persons, who although possessed of great general intelligence, have collected blue stones (generally ores of copper) for cobalt, ignorant of the fact that none of the natural combinations of this valuable metal possess a blue colour.

The sulphate of baryta has for a few years past borne a certain value for manufacturing purposes; and an instance was brought to my notice, where a ship-load of what was supposed to be this mineral was obtained by surreptitious means, and sent from a distant part of the country to London. But the biter was bit, for his observation was faulty, and his cargo, proving to be calcareous spar, was worthless. It would tire out your patience to enumerate the cases in which mica or iron pyrites have been mistaken for gold. From the anxious country gentleman in our own land, to the disappointed Californian gold seeker, and to the solemn Turkish Bey mysteriously unwrapping from many a folded rag the specimen of his expected wealth, such victims of mineralogical ignorance are frequently presented to those whose pursuits bring them into a position for advising on similar points.

But there is another and a wider field far more important

than the correction of isolated mistakes, in which mineralogical research has yet to be largely employed, and in which the connexion of this subject with mining is no less grave than intimate. The principles by which the accumulation of ore in lodes or metalliferous veins has been regulated are to this day so enveloped in mystery, that the prosecution of mining enterprizes is almost as much a matter of chance as it was with our forefathers three centuries ago. Nor can we wonder that this should be the case, when we regard the peculiar difficulties by which the subject is beset. Not only is the progress of the operations so slow that the observation of one set of phenomena may extend over many years, but the examination of some points, unless made at the time of first opening, is precluded by the discolourations of water and powder smoke, or by the means adopted to secure the works. Then, according to the conditions under which the lode is placed, a combination of problems, geological, physical, and chemical, are presented for solution, and the thoughtful mining agent, left to consider them only by the light of a partial experience and natural shrewdness, is commonly led to see them through a peculiar medium, and to fall into the numerous errors resulting from unsound premises. Copious stores of knowledge have, it is true, been acquired by many of the captains and tributers in Cornwall and elsewhere; but besides the difficulty, according to the various views of individuals, in collating them, they have generally, from want of early educational opportunity, been accumulated upon an unsafe basis; and finally, the experiences perish with the men, leaving society no richer for their acquisition.

Nowhere is there more room than in the study of this subject for accurate mineralogical observation,—nowhere is the prize offered more inviting; for the resolution of some of these questions must tend to acquaint us with the probability of finding remunerative ores in certain directions, either in depth or on the course of the lodes, and must, therefore, be instrumental in discovering untold sources of wealth. Nor need we despair, when we remember the confused state of all the natural sciences little more than a hundred years since, that at some future day a more systematic cultivation, by rigorous induction, founded on

close observation, will clear away the weeds, and cover with plenteous crops this hitherto barren field.

We are thus naturally led, by the contemplation of the objects to be sought for, to the second part of our subject, the Art of Mining: and here it will be necessary to dwell at greater length on the character of the studies which it is desired to embrace, inasmuch as no course of instruction in them has yet been attempted in this country; and, strange to say, not a single book exists in the English language in which they are comprehensively treated. Among the Germans many excellent works on mining have appeared from time to time during the last three centuries; and even in France, a country comparatively so poor in mineral productions, treatises have been published, in which many of the divisions of the subject have been skilfully discussed, whilst the periodical literature of both those nations is rich in detailed descriptions of the natural phenomena and the working processes of mines in all parts of Europe. Nor are we unindebted to the Russians, whose well-educated officers of mining engineers, sent at the public expense to investigate various mineral regions of the continent, have carried back with them a treasure of valuable information, which has been in a great degree instrumental in advancing, to a high grade of perfection, the mining and metallurgical operations of the Ural and of Siberia. In Britain, however, we have little else than two or three treatises on the working of coal, and a few isolated papers on other parts of the subject; and hence it will be needful, in a series of Lectures, to depend in great part on personal experience, and to indicate, in exceptional cases, the sources whence a knowledge of details may be obtained.

But it would be an injustice to the many thinking and enterprising spirits among our British miners not to express our admiration for the skill and ingenuity which they have brought to bear on particular portions of their art. Surrounded by difficulties and dangers, they have won enduring triumphs; and in some of their applications have, by the force of persevering industry, advanced their experience with such rapid steps, that science has been glad to follow in their wake, and reap new facts to aid her further progress.

The first great feature which strikes the attention in approaching this subject is the enormous value of the mineral productions of Great Britain, amounting, as has already been stated by our honoured Director in Chief, to the sum of 24,000,000*l.* annually in the rough state. So bountifully, indeed, has our country been enriched by Providence with these sources of wealth, and in a degree so much higher than any other region in Europe, that it need excite no surprise if those natural gifts which even aroused the industry of the early Britons, and excited the cupidity of their Roman conquerors, yield at the present day an amount of riches far greater than those produced by any other nation. Let us, then, consider the great population supported directly by the extraction of these minerals, and indirectly by their application to the arts,—the maintenance of hundreds of thousands of men by these not inexhaustible stores,—and the entire dependence of our whole manufacturing and commercial system on the supply of fossil fuel; and we cannot fail to arrive at the conviction, that in exercising the stewardship of such gifts of Heaven, the nation has a high and responsible duty to perform, that waste and improvidence are a national sin, and that it behoves all who are in any way connected with the working of our mines to lend their best endeavours to the perfecting of the most economical and efficacious means of rendering all the products of our mines available to the uses of mankind.

It is not pretended that by any plan of education in an Institution of this kind, it is possible to make a miner, or in other words, to prepare a man for taking charge of a mine as soon as he has left our walls: not more reasonably should we expect that a lad drilled in the classes of a naval college were at once metamorphosed into a sailor, fitted at once to take command of a ship. Yet surely no one will deny, that if in that school he has learnt to box the compass, to knot and splice, if he has worked out problems in navigation on sound mathematical principles, if he has been taught by descriptions how to handle a vessel at anchor in a tideway, or on a lee-shore, he will be infinitely more ready to take advantage of circumstances, and to make rapid progress, than if he had been sent

on board unknowing of these things and their principles. No "royal road" to learning, no legerdemain of "cramming," can make amends for the want of time and pains bestowed on the acquisition of practice; and as with the seaman so should it be with the miner.

By description, by drawings, and models, it will be our endeavour to make the student familiar with the chief phases of the operations practised in various regions, and under different conditions. He will have, each year, the opportunity of closely inspecting the mineral features and particular mining processes of the districts under examination by the Geological Survey; and, when furnished with this preliminary knowledge, will, I doubt not, pass to his sphere of probation better qualified to observe and to compare; whilst the practical experience which he must afterwards acquire will be superadded to what he has already benefited from the labours of others.

Before we proceed to examine farther into the general question of the importance of endeavouring to establish in Britain a system of technical education for this department, let us consider the definition and principal heads of the subject before us; and, whilst so engaged, let us take an instance from each division, illustrative of the gain to be derived from an extended acquaintance with the modes of treating it.

The art of mining comprehends all the processes whereby the useful minerals are obtained from their natural localities beneath the surface of the earth, and the subsequent operations by which many of them must be prepared for the purposes of the metallurgist.

In the first place, among these processes must be mentioned, the search for localities in which we may reasonably hope to meet with the minerals occurring either in beds or lodes. It is obvious that a combination of geological and mineralogical knowledge is requisite for success, and that a mere empirical tact obtained in a given district may lead to fatal mistakes in another. Amid the phenomena of the lodes, their frequent heaves and dislocations, and their different appearance when bounded by different rocks, call for close attention; and although from lack of sufficient and well recorded observation, the prin-

ciples upon which a criterion should be founded are far from fixed, we often find that a superior degree of general experience has been rewarded by success, when mere unintelligent working had been completely foiled.

Among the methods of proving the existence of useful deposits, none has yielded greater results, or is more capable of extended application, than the art of boring. For ascertaining the position of coal-seams, and for obtaining a supply of water, bore-holes are frequently sunk in many parts of the country. But we have yet, by a comparison of the practice of different countries, and the adoption of a more economical mode of sinking, where need be, to greater depths, to increase their sphere of utility. At Neusalzwerk, near Minden, a bore-hole has lately been pierced through the trias formations, to the depth of 2,300 feet, for brine springs; and another, at Mondorf, in Luxembourg, to near 2,400 feet, which, though unsuccessful in discovering salt, has supplied a spring of above 21 cubic feet per minute. At these and various bore-holes of less depth in Germany and France, a variety of apparatus has been employed, a complete study in itself, much of which has been serviceable in greatly reducing the time and cost of such operations. We may instance the ingenious instruments of M. Degousée, the "free-falling" cutter of Herr Kind, and the hollow iron rods of Von Œynhausen, as a few of those which are well worthy of attention for the good service rendered in the execution of great works. Again, we know far too little of the routine of the Chinese well-borers, who have succeeded, according to the detailed statements of Father Imbert, in attaining the extraordinary depth of 3,000 feet, by their simple and inexpensive apparatus of rope-boring, an example which has been successfully imitated in the chalk districts of France.

The next division of importance embraces the tools used in mining. One of the greatest advantages which we enjoy over our forefathers is the use of gunpowder in rending a path through the harder rocks, which they with enduring and patient labour were obliged to cut away with hammer and wedge. But the implements employed in various districts differ not only in form and weight, but in their material and useful effect. Let me

only allude to one point: in scarcely any of our mines, whether in the north or south, has it been attempted to use borers of steel; iron is almost universally, with us as in most parts of the continent, the material of which the shank of the borer is composed. Yet in Saxony, for many years past, as also in Derbyshire, and at Ecton, the work has been advantageously carried on with borers of steel alone. Accurate experiments made and recorded at Eschweiler, and at Mannsfeld in Prussian Saxony, have been attended with favourable results; and Mr. Rogers of the Abercarn Collieries has succeeded in proving, whilst sinking a large shaft in hard rock, the value of steel tools, a set of samples of which were placed in the Great Exhibition, and afterwards presented to this Museum. Although the suitable tempering of cast steel is attended with some difficulty to the inexperienced, the following reasons for its preference to the ordinary material have been established, viz., the great saving in wear and tear; the reduction of original outlay, since the stock of steel borers may be smaller than that of iron in a lower ratio than that borne by the price of iron to steel; the diminution of smith's costs for sharpening, and of time lost by boring with a blunted edge, and the greater convenience of carriage in and out of the mine. Farther, the superior compactness of the material transmits the force of a blow more efficaciously to the required point, a fact corroborated by the observation that an iron borer will cut less ground with the same number of blows when new than after being for some time in use; And it need hardly to be added, that in the questions of time, material, and cost, connected with the breaking of ground, we touch on some of the most important elements of economy in mining.

I will not detain you with an enumeration of the points to be dwelt upon in the form of the excavations by which we enter into the earth, whether by the driving of levels or the sinking of shafts under different circumstances; nor, from among the modes of securing them by timbering, masonry, or ironwork, shall I do more than bring to your notice one ingenious application of physical science to these purposes. It is well known that the sinking of a shaft through loose sand or watery rock often besets with great and sometimes with insurmountable ob-

stacles the approach to the useful minerals which lie in firm ground below. On the banks of the Loire repeated efforts to reach the coal measures through a thick bed of alluvial sand had failed, overcome by the great influx of water and loose material; when M. Triger bethought him that the simplest mode of vanquishing the difficulty was to dam back the water by employing a constant resisting force which might be maintained at small expense, in place of a moving power of enormous cost. It was, in fact, to pump into the iron cylinder which formed his shaft such an amount of air that the pressure on the bottom from within should be equal to the pressure from without; and the water was thus prevented from rising above a given height. Placing a cover on the cylinder, through which two pipes are inserted, one conveying the compressed air into it, the other dipping into the watery stratum, he found a stream of water and sand poured through the latter whenever it was unable to escape rapidly enough elsewhere. Then, in order that the men might enter upon or leave their working place without disturbing the equilibrium of the forces, he applied the principle of the canal lock, fitting an upper chamber in his shaft, where, when the upper door was closed and the lower one opened, all was filled with the compressed air; when the lower one was closed and the upper opened, the air-lock was relieved from its superabundant air, and men or materials might be introduced. Pages would be filled with the details of the difficulties met and overcome, and of the successful adoption of the principle in the sinking of larger and deeper shafts; suffice it to say, that M. Triger succeeded, surrounded by water, in joining his cylinder to the solid rock at a depth of 82 feet from the surface, having proved that human life could be supported, and work done, for many hours together under a pressure of 3½ atmospheres. His procedure is marked by manifold advantages, and admits of various applications;—witness the removal of rocks in the harbour of Croisic, on dry ground, whatever the state of the tide. Verily, if Canute had possessed a Triger among his courtiers, he might, to better purpose, have defied the rising flood to touch his royal foot!

We shall be unable here to glance even rapidly over the many systems devised for working out the minerals attained by

the foregoing operations: let us only scan an isolated case. The magnificent seam called the "thick coal" of Dudley has been worked throughout the entire field on a principle which by taking the whole height, 30 feet, at one time, has been attended with such danger as to cause almost weekly some frightful and fatal accidents, and to exercise morally a pernicious influence on the character of the colliers; whilst it has necessitated the leaving of so large a proportion in "pillars" and "ribs," that only from 11,000 to 15,000 tons of coal have been obtained out of 40,000 contained in the acre. Here then is a loss to the national wealth of useful life, and of about two thirds of the finest fossil fuel in Britain, the money value of which would amount to many millions. Yet for twenty years past, in that very district, one group of pits has been worked on a system by which the coal is taken in two successive stages, where the men work in comparative safety, and where, instead of 11,000 or 15,000, 26,000 tons are realised per acre, although the seam is there of less than its average thickness. Consider only for one moment the beneficial effects of improved means of extracting the coal from our mines: it is supposed that the total quantity annually brought into use amounts to above 30 millions of tons; and if an economy of but threepence per ton were effected, by reducing friction, ineffective labour, or other sources of wasted power, a sum of nearly 400,000*l.* per annum would be saved to the country.

We must omit to speak of the modes of transport along the underground roads, of raising the minerals to the surface, and of pumping the subterraneous water, accomplished by an amazing variety of apparatus and machines. Nor can we dwell upon that important subject of ventilation, to which our attention is so often and forcibly called by the fearful catastrophes occurring in our mines from its absence or mismanagement. I would only call attention to the rude method of dispersing noxious gases figured by Agricola 300 years ago, and in some of our districts still adopted, under the term of "brushing out the sulphur," as the only means of rendering a place safe for the men to work in. But although even at that early day more refined processes had been introduced, as evinced by his description of

the ventilating fans, let us compare all those puny means, and the efficiency of ventilation in the great bulk of our collieries with the skilfully applied and fiercely blazing furnaces of some of the great northern mines, where a current of 150,000, or in one case near 200,000 cubic feet of air in one minute are circulated through the devious passages, and rush to the upcast shaft with the velocity of a hurricane.

Nearly related to this division, as regards the question of humanity, is the true construction and the preservation of mining plans. Take an instance in which the loss of 100 lives may ensue from the ignorance of a physical fact. Those familiar with the mining districts are well aware that the great majority of their maps are laid down without any reference to the phenomenon of magnetic variation. If, then, a colliery be in operation on the dip of old workings filled with water, the tapping of which would be death to all employed in the pit, and the maps had been constructed some years previously with respect to the magnetic meridian alone, the variation may in the mean while have so far changed that the exploring drifts supposed by the manager to be going clear of the known danger may, in reality, lead him straight to destruction. The art of surveying is, however, too important and extensive to be included in the lectures on Mining, and will ultimately, we hope, form the subject of a separate course.

The last group of operations to be included is the dressing of ores, on the efficient conduct of which the success of many a mine may depend. Whilst the Schemnitz miner is able to work actual gold ores broken from great depths, which, besides a little lead, contain no more than one part of gold in 228,000 of stone,* and whilst the Russians wash in their stream-works sands containing only one part in half a million, we learn from description that the Californian and Australian are employing processes more rude than what they might have copied from the miners

* In 1841-2, when I passed some months among the mines of Hungary, much had been done and was still doing by my friends the late Oberstkammergraf von Svaiczer and Mr. Rittinger, the Inspector of Stamp-works, for the improvement of the dressing of gold and silver ores; and the works at Antal and Illia, near Schemnitz, were well worthy of admiration for their scale and economy.

of three or four centuries since, and that (inasmuch as the poorer part can only be profitably worked in conjunction with the richer) they are actually losing for ever a large proportion of the riches showered by nature upon those lands.

Such are, in few words, the processes which will form the substance of a course of instruction in the art of mining; and it need scarcely to be observed that a preparatory acquaintance with physics, geology, and practical mechanics is indispensably necessary. For this reason it is proposed that the Lectures on Mining shall be given to the students of the second year, already provided with the preliminary studies, some of which have been commenced; but in order to obviate misconstruction, it is proposed during the present season to deliver a concise course, intended simply as an outline of the subject, leaving the more detailed treatment for the ensuing year.

Amid the entire circle of the sciences we can hardly mention one which the accomplished miner may not at some time call to his aid, from the science of numbers, on which all his other knowledge should be based, up to astronomy, which may assist in the construction of his maps. We cannot, indeed, expect that many will become, like Humboldt, (who was educated, and for some time practised, as a miner,*) master in several sciences; but when we add to these the acquaintance with business routine and commercial questions which the manager of mining property ought to possess, is it not clear as the noon-day that for those who desire to excel in this profession a special education ought to be superadded to the training of our schools and colleges? And is it not equally clear that with so vast a field of investigation before him the intelligent inquirer must ever remain a student, whilst only the shallow pretender can affect to be the arbiter of the difficult problems which daily present themselves?

From the examples above adduced I trust that I shall be justified in asserting, that a communication of knowledge, whether of the principles or of the practices involved in mining, must be

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* Alexander Von Humboldt was a student at the mining academy of Freiberg, in Saxony, in 1791, with von Buch, Freiesleben, and other coryphœi of mineralogical and geological science.

attended by great pecuniary gain to the country at large. We shall be met, in the outset, by the argument more suited to the Cape Boer or the Chinese than to the progressive Anglo-Saxon, that because our fathers have done very well without it we may easily dispense with any such innovation; and that the immense mineral production of Britain is the best proof that we need not to follow the example of nations unable, with all their schooling, to rival us in that respect. But let us not overlook the great natural advantages with which we have been favoured, nor forget, that although individual perseverance has done much, very much, among us, we must still depend for advancement in a great degree on the experience of others. In good truth "he that neglects the culture of ground naturally fertile is more shamefully culpable than he whose field would scarcely recompense his husbandry: and it is as rational to live in caves till our own hands have erected a palace, as to reject all knowledge of architecture which our understandings will not supply."*

Taking even the present state of our knowledge as a standard, let us balance the argument on such crucial questions as the following. Do cases occur in which mineral substances are neglected from ignorance of their nature? Is it true or not, that others are wasted and lost to the nation by the character of the present operations? Do not crowds of well-meaning adventurers rue their introduction to the mining schemes of impostors? Are not hundreds of human lives sacrificed to a want of precaution and prudence? Is not the condition of machinery and apparatus in a great part of the country very inferior to certain now existing models? Are there not numerous sources of wealth lying unemployed from the uncertainty consequent on a want of former records or present knowledge? No one, I am confident, acquainted practically with our mineral districts, will hesitate in replying, that in all these points great and salutary changes may be made, and that enlarged opportunities of learning accorded to the mine agents must produce their fruits in due season.

As for the miserable plea of ignorance, that the country cannot

* Johnson. Rambler, No. 154.

fail to prosper, in whatever degree her sons may squander the stores of nature deemed inexhaustible,—it but leads the mind back, through many centuries, to an instance of similar reckless boasting, followed by a warning fate. In the palmy days of Athens, when the silver mines of Laurion were vivifying art, commerce, and luxury, Xenophon asserted, in a formal treatise on the revenues of the state, that "whatever number of men had been employed in those silver mines, no diminution had been practically effected in the quantity of the ores;—that there was no limit to the productiveness of the veins, either in depth or in extension, and that their riches, in fine, were inexhaustible."* Let any one contrast such assurances with the beggared state of the land ever since.

I would be far from strictly comparing the conditions of Attica or its people with our own; but we must bear in mind, that in all our mining districts the minerals are extracting at a fearful rate, and each year in an increasing ratio, and that after a certain lapse of time scarcity and increase of price must necessarily follow. In the meanwhile, we have numerous rivals in other and less favoured lands, doing their utmost to make up for natural disadvantages by fostering education and acquiring a sound knowledge of the principles on which they act. In this race they have often been checked by political troubles and peculiarities in their social relations; but, having so thoroughly secured each onward step as to be comparatively independent of the fleeting skill of individuals, they nevertheless press forward again in the same path; and when the day comes that our preponderance in natural treasures is reduced to something nearer equality,—when deeper and thinner coal seams must be wrought, when poorer ores of the metals must be more highly prized, and when the products of our manufactures can only be brought into commerce at higher prices,—then must the star of England's prosperity decline, unless we keep our vantage ground by the

* Μαρτυρεῖ δὲ κἀκεῖνο, ὅτι, εἰργασμενῶν ἀνθρώπων ἐν τοῖς αργυρίοις ἐν τῷ παντὶ χρόνῳ ἀναριθμήτων, νῦν οὐδὲν διαφέρει τα ἀργύρια ἢ ἃ οἱ πρόγονοι ἡμῶν ὄντα ἐμνημόνευον αὐτα. . . Οὔτε γὰρ βάθους πέρας οὔτε ὑπονόμων οἱ ὀρύττοντες εὑρίσκουσι.—*Xen. de Vect.* c. IV.

superior skill and knowledge to which technical education must greatly contribute.

Thus far we have directed our attention almost exclusively to the material advantages, or, in other words, the pecuniary returns to be expected from the cultivation of these subjects. I have dwelt so long on such topics because the main object of the foundation of this course of instruction has reference to that point of view.

But I should ill appreciate the character of this audience, and do violence to my own feelings, were I not, in conclusion, to protest against that debasing spirit which would decry all branches of knowledge except those which are at once commercially profitable, and which would practically inculcate a belief that the acquisition of money is intended to be the great end and aim of human existence. Shall we, for their own sake, examine the works of the architect, the painter, or the poet, and analyze the rules upon which his art is founded, whilst we yet remain indifferent to any one department of the rich storehouse of nature, opened for man's inspection by the Author of all things?

Believe me, that the phenomena of mineralogy, and the principles which regulate them, are, though different in their kind, no less beautiful than those of animal and vegetable life; and they possess the additional source of interest, that they may guide us to the wider sphere of speculating rationally on the constitution of the orbs which roll with us through endless space.

With reason has a Turkish author* said, "Consecrate, O my son, the aurora of thy reason to the study of the sciences; in the vicissitudes of life they are an infinite resource, they form the mind, they polish the understanding, they instruct man in his duties, they delight and amuse us in prosperity, they become our consolation in adversity." Indeed, to the student in his cabinet, no less than to the traveller through Alpine passes, or over regions explored by the skill of the miner, the study of minerals offers at the same time an attractive

* Nabi Effendi, a counsellor of Sultan Mustapha III.

recreation, and an efficient method of disciplining the faculty of observation. The closer we investigate the principles on which their constitution and their physical properties depend, the more are we startled by new and convincing proofs that it is only the imperfection of our knowledge which as yet prevents us from seeing more than the glimmering outline of that harmony which pervades all the works of nature. The system of law, the *νόμος ὁ πάντων βασιλεὺς* of Pindar, working as surely in the particle which vanishes from our power of sight, as in the loftiest mountain mass, reveals itself with more distinctness the farther we advance; and although the difficulties of inquiry are heightened, so are its pleasures also increased by the ties of brotherhood, which springing hence unite our pursuits with the other natural sciences.

Nor let it be supposed that the details of mining are unproductive of advantage to any but the professional miner. Deep in the bowels of the earth the labour of generations has wrought out edifices no less worthy of admiration than those which the skill of the architect has reared upon her surface; and if, in the latter case, we esteem it desirable to learn so much of the principles of the art as may enable us to appreciate the design of the craftsman, so in the former shall we find in the magnitude of the operations, in the diversity of the natural appearances brought to light, and in the ingenuity of the processes adopted for the maintenance and extension of the works, a harvest of facts no less interesting than suggestive of farther inquiry.

Whatever may be the imperfection of the teacher of these subjects, there is in themselves so much that is exact, so much that is vast, so much, in fine, that is most worthy of man's highest powers, that we may hope, out of the number who will enter with us on the curriculum, to see some few, at least, who will not stop short at that point whence they may obtain their worldly ends, but will persevere towards that goal of higher knowledge which has been, and always will be, the object of the noblest of mankind.

On the Importance of Special Scientific Knowledge to the Practical Metallurgist. (Being the Introductory Lecture to the Course of Metallurgy. Session 1851–1852.)

By John Percy, M.D., F.R.S.

The subject which I have been appointed to teach in this Institution is essentially practical in its character and relations. In the introductory discourse, which I am now about to deliver, I shall explain the nature and object of the instruction which I propose to impart, and point out what I conceive to be its advantages.

Metallurgy, as at present understood, is the art of extracting metals from their ores, and adapting them to various purposes of manufacture. This definition, however, is not rigidly exact, nor can I frame one in few words that is so.

The etymology of the word "metallurgy" would seem to imply a more extended meaning, and include all the arts in which metals are wrought into objects of utility or ornament; but this is not the meaning now attached to the word.

The metallurgist receives the ore from the miner freed as perfectly as possible by mechanical processes from foreign matter.

The knowledge of the principles of metallurgy is the science of metallurgy. But as the phenomena observed in metallurgical processes relate to physics and chemistry, and as mechanical appliances of various kinds are employed in these processes, it follows that chemistry, physics, and mechanics must be the foundation of the science of metallurgy. In order, therefore, that the student may with advantage enter upon the study of metallurgy, it is essential that he should possess a considerable amount of preliminary knowledge.

The history of metallurgy dates from remote antiquity; and, as Le Play correctly observes, "most of the fundamental phenomena of metallurgy were discovered and regularly applied to the wants of man before the physical sciences properly so called existed."* Metallurgy may, indeed, be said to have given birth to chemistry.

My colleagues having addressed you at some length on the aid which science may be expected to render to the manufacturing arts, it might appear superfluous that I should occupy your attention with the same subject. I shall, however, do so for two reasons:—first, because I shall be able to adduce from my own observation several striking cases in illustration of the advantage of the application of science to practical metallurgy; and, second, because the practice of metallurgy, so far as relates to magnitude of operation, having been developed to an unparalleled extent in this country in the absence of specific public instruction on the subject, it is necessary to justify the providing of such instruction at the present time.

As the word "science," in relation to a manufacturing art, is often used by persons who seem to have no precise idea of it, I shall first adduce a simple illustration of its meaning. There is an ore of copper, composed of copper, iron, sulphur, and silica. When such an ore is subjected to a series of processes consisting of heating it with the access of air, melting, &c., copper is separated in the metallic state. The sum of these processes is termed the smelting of copper. Now in this operation of smelting various chemical changes take place; the sulphur combines with the oxygen of the air, and is evolved in a gaseous state; the iron also combines with the oxygen of the air to produce oxide of iron, which combines with the silica to form a slag, while the copper is separated in the metallic state. We have thus several facts, which are proved by chemical evidence. These facts may, when properly arranged, be said to constitute the scientific knowledge of copper-smelting; and that knowledge implies necessarily a knowledge of the chemical relations of copper, iron, sulphur,

* Le Play. Description des Procédés Metallurgiques employés dans le Pays de Galles pour la fabrication du Cuivre. Paris, 1848.

oxygen, and silica to each other. There are also many other facts connected with copper-smelting; but those which I have selected are sufficient for the present purpose of illustration. Now, the man who conducts the process of copper-smelting in ignorance of these facts has simply an empirical knowledge, in contra-distinction to a scientific knowledge, of the process.

That a scientific knowledge of the process may be important to the man who directs copper-smelting works would hardly seem to require an argument. It may, however, be objected, that the process is often satisfactorily conducted by men whose knowledge is purely empirical. Now the objection would have some weight if it were admitted either that the process is incapable of further improvement, or that the ores upon which such men are accustomed to operate were not liable to vary in composition. But such an admission would be a purely gratuitous assumption; and the ores do occasionally contain unexpected ingredients, which, in the event of precisely the same process of smelting being pursued, would tend in a very sensible degree to deteriorate the quality of the copper produced. Hence, ignorance of the presence of such ingredients on the part of the smelter may occasion pecuniary loss; and, in ignorance both of the causes which thus may injure the copper and of the scientific knowledge of the process of smelting, he is certainly not in the most favourable condition for devising an appropriate remedy. It is true that by a series of blind trials a suitable modification of the process might be stumbled upon; but it is equally true that with the aid of special scientific knowledge there is much more probability of arriving at a solution of the difficulty with far greater economy of time and money. The case which I have put is not imaginary, but real; nor is it, as I know from my own experience, a solitary one. When I treat of copper smelting I shall enter into detail upon this subject.

In support of the general proposition, that special scientific knowledge is important to those who direct metallurgical processes, I shall now present to your notice several cases, most of which I can myself substantiate.

A party purchased a large quantity of a particular ore, at the cost of many thousand pounds. Another party purchased at the

same time a much larger quantity of the same ore, at the same price. To treat this ore profitably, special scientific knowledge was essential. The former party possessed that knowledge, and gained thousands by his purchase; but the latter had it not, and lost money.*

A manufacturer purchased some metallurgical works, and for certain miscellaneous articles on the premises, including a heap of waste product, gave only a very inconsiderable sum. Out of that heap, which in ignorance had been thrown aside as worthless, he realized sufficient to pay for the works, the price of which amounted to several thousand pounds.

An eminent copper-smelter informed me, that his ancestor, in purchasing some old copper-works, obtained in value more copper from the furnace bottoms than the purchase-money. In this instance, perhaps, negligence might be ascribed to the seller, but in that last mentioned the error was the result of sheer ignorance.

In 1841 a patent was taken out for "certain improvements in the manufacture of iron and steel." The invention mainly consisted in soaking the pigs of iron in cold water previously to their introduction into the puddling furnace.†

Again: a short time ago a patent was obtained for plating certain metals and alloys with a particular metal, and a manufactory was erected at a considerable outlay to carry out the invention. It was alleged that the importance of the application consisted not only in the whiteness of the metal employed, but in the economy of the process. Now the metal in question was at that time at least thirty times dearer than tin, and was produced only in small quantity. But the inventor was sanguine, and assured me that an ore containing forty per cent. of it existed in abundance, whereas the fact is, that only a few

* It would be impossible for me, without breach of confidence, to enter into more specific details in the narration of this and the following instances.

† Patent granted to Wm. Turner Green and James Gregory, of West Bromwich, Staffordshire, for certain improvements in the manufacture of iron and steel, May 14, 1841. A report of this patent has not been published, but the original document may be seen at the Enrolment Office.

ounces of such an ore have ever been discovered, of which specimens are rare even in mineralogical cabinets; and the ores which contain it and occur abundantly in nature do not yield more than two or three per cent. of it. This case, it is true, may be regarded rather as indicative of ignorance of mineralogy, than of metallurgy; still it may be appropriately introduced under the present head, as an argument for the necessity of the diffusion of accurate scientific knowledge amongst metallurgists. The inventor speculated on the probability of a demand creating an adequate supply of the metal at a comparatively small cost; but special scientific knowledge would at least have prevented the precipitate investment of capital on such a speculation.

Facts such as I have just mentioned should be a warning to the numerous class of inventors in this country, whose naturally sanguine temperament is liable to disturb the exercise of their judgment. The published records of patented inventions, indeed, furnish a striking commentary on the proposition before us. The diffusion of the scientific knowledge relating to metallurgy would often prevent the reckless expenditure of money on worthless patents.

Very striking instances in support of the same proposition may be derived from the important branch of metallurgy termed "assaying," or the art of determining the quantity of metal contained in its ores, alloys, or certain other compounds. Without a correct assay, it is obvious there can be no certain knowledge of the value of an ore; and without that knowledge, the purchase of an ore by the smelter is merely a speculation. Now by great practice upon some particular class of ores, the merely practical assayer may arrive at accurate results, and yet be entirely ignorant of the science of his art, or, in other words, of the chemical properties and relations of the elements upon which he operates. But if, as I have already mentioned in the case of the copper-smelter, he should meet with an ore containing foreign and unexpected ingredients, which interfere with the accuracy of the method he had been accustomed to practise, he would not, from his want of scientific knowledge, be able to surmount the difficulty, and would consequently, from his necessarily erroneous result, seriously mislead the smelter respecting the

value of an ore. Or he might equally mislead the seller who relies upon his judgment, either by under-estimating the quantity of the particular constituent which he seeks to determine by his assay, or by overlooking another constituent, it may be of great value. In illustration of errors of this kind, I have selected the following instances.

An ore of cobalt from North America was assayed, and alleged to contain twenty per cent. of oxide of cobalt, which at the time was worth about 30*s.* a pound. The assayer, however, had made an important mistake; for what he had estimated as oxide of cobalt consisted of oxide of cobalt and oxide of manganese, in the proportion of two parts of the former to three of the latter; the oxide of manganese being in this instance not only utterly valueless, but positively injurious.

An experienced copper-assayer, on assaying a particular ore, obtained what he believed to be nickel-speiss: that is, a compound of nickel and arsenic. Now, nickel is a valuable metal, being worth at the present time eight shillings a pound. But the supposed speiss contained not a trace of nickel, and was proved to be only a compound of iron and arsenic, a comparatively worthless product. On the ground of this assay, I believe a quantity of ore had been dressed for the market.

The following is a curious and remarkable instance of the importance of accurate chemical knowledge to the metallurgist. The Upper Hungarian Mining Company smelted, during several years, a species of copper-ore termed fahlerz, in ignorance of the fact that it contained mercury, which was ultimately discovered by the accidental observation of a workman. Means were then adopted to collect the mercury, of which the present annual produce amounts to 30,000*l.* in value.*

Not along ago I visited, in concert with my friend Mr. Henry, a tin-plate manufactory. In the first part of the process of tinning there is constantly formed a black powder, which from time to time is removed from the surface of the melted tin. On interrogating the manager, who conducted us over the establishment, it appeared that he was ignorant of the nature of that

* My friend Professor Szabó, of Pesth, is my authority for this statement.

powder, which Mr. Henry on subsequent examination found to contain 62 per cent. of tin in a finely divided state. Our guide suspected that it contained silver; but his knowledge was limited to the fact that, whereas it was formerly thrown into the adjoining river, it was afterwards sold for a few pounds a ton, but now realized ten times as much.

Occasionally a large sum of money may depend upon an assayer possessing a profound knowledge of certain departments of analytical chemistry. Thus, not long ago there was a dispute between the Bank of England and the Mint respecting the recoinage of a million of sovereigns. On melting the gold at the Mint several pounds weight of a metal were obtained which had not been previously detected by the assayer. That metal was chiefly iridium, which had been simply mechanically diffused through the gold, and which, in the state in which it was separated, was comparatively valueless. The question then arose whether the Bank or the Mint should be responsible for the loss; and it was some time before a satisfactory conclusion was arrived at. I do not mean to imply that the slightest blame was due to the assayer in this case, because he had no reason under the circumstances to suspect the presence of iridium in sensible quantity. I relate the fact, simply to show that an assayer of the precious metals may be called upon to determine the presence or absence of iridium in gold, and, I may add, of other metals also, which, for their satisfactory detection, require no ordinary skill in one of the most difficult departments of analytical chemistry.*

It would be impossible to insist too strongly upon the importance of assayers generally receiving sound instruction in the specific department of analytical chemistry, which relates to assaying.

Did time permit I could adduce many more instances in support of the proposition, that special scientific knowledge may be important to the metallurgist. I could mention one case in which, I have been credibly informed, thousands of pounds

* The presence of minute particles of the alloy of osmium and iridium in gold is sometimes very annoying to jewellers and watch-case makers.

worth of gold were lost by a blunder; and others, in which the want of scientific knowledge had occasioned heavy loss; but I have preferred placing before you those instances only upon the accuracy of which you may rely, as I have derived them either from personal knowledge or unquestionable authority. But it will not, I think, be denied, that the instances which I have adduced of themselves afford sufficient evidence of the importance, not to say necessity, of special scientific knowledge to those who are intrusted with the direction of metallurgical works. The interests at stake in such works are frequently very great, and we have seen how injuriously those interests may be affected by the want of such knowledge.

It must not be inferred from the foregoing remarks that I undervalue practical knowledge. So far from this, I am convinced that scientific apart from practical knowledge may in metallurgical establishments lead to most erroneous and occasionally ruinous results. Metallurgy is an art, and, like every other art, can only be acquired by experience. In many processes success depends upon the discrimination of appearances so slight that the eye, in order to detect them, requires to be educated by close and constantly repeated observation. No description, however accurate and minute, would enable a man, though a shrewd observer, to recognise at first such appearances, and consequently to conduct processes in which success essentially depends upon their detection. To understand adequately the force of these remarks, a practical acquaintance with certain metallurgical processes is necessary.

The descriptive expressions occasionally used by the practical man may appear to be vague, and he may not be able to define them in language very intelligible to us; yet we may generally be sure that they express correctly the result of his observation, and have a meaning well understood by himself. For instance, on inspecting a blast-furnace in Staffordshire, I perceived that "tap-cinder" (slag from the puddling-furnace, rich in iron,) was introduced into the furnace with a mixture of iron ores, not then a very unusual and now a common practice. I accosted the foreman of the works, and asked him his opinion concerning the effect which he supposed the use of "tap-cinder"

would produce upon the iron. His reply was, that "cinder has no nature in it." Now the term "nature" expressed his experience of the quality of the iron when "cinder" and ore were smelted together; and, as I knew what that quality was, I knew exactly what was meant by the term in question.

The knowledge of the science of a metallurgical process would of itself be a very insufficient qualification for the man who directs the manufactory. Let a chemist, for example, who may perfectly understand the theory of copper-smelting, but who is entirely ignorant of the practice of the art, attempt to take the management of copper-smelting works, and he would find himself embarrassed at the outset: he would not be able to form a correct judgment in a single step of the process. Without experience he could not decide whether the requisite degree of heat was produced in any of the furnaces, or whether any of the various operations of smelting had been properly effected. Again: let the chemist who has received his education exclusively in the laboratory, and who, consequently, has only been accustomed to deal with small quantities, be simply required to dissolve a ton of copper in sulphuric acid, and at first he would not be a little perplexed: he would find how different the manipulation of the laboratory is from that of the manufactory; he would have to consider of what material he should construct the vessels in which to effect the solution,—of what form and size they should be,—and in what manner heat could be best applied; only the chemist who is himself practically acquainted with the manufactory will well understand the force of these remarks. I have frequently conversed with chemists who have supposed that their chemical education alone rendered them at once fully qualified to conduct operations on the large scale; and who have expressed themselves disparagingly of the practical man. Let such men attempt to conduct the manufactory, and, in all probability, it would soon be seen that the price of their obtaining the requisite practical skill would be heavy loss to the proprietors.

We are thus led to the conclusion, that while scientific knowledge alone will not qualify a man to take the management of metallurgical works, so neither is empirical knowledge

the only qualification desirable in such cases; it is clearly the combination of scientific with practical knowledge that will render the managers of such works in the highest degree competent for their responsible positions. And, accordingly, we find that our manufacturers have begun to appreciate the importance of this combination of knowledge in their managers. I could mention several establishments in which the aid of science has been sought with no inconsiderable advantage. I know that men who have received a metallurgical education on the continent are now employed in metallurgical establishments in this country; and I know many instances of English students seeking that instruction in mining and metallurgy abroad which had not been provided for them at home. It is from the combination of scientific with practical knowledge, especially in metallurgical establishments, that we may reasonably expect improvements in metallurgy. The scientific man, without practical knowledge, is likely to project schemes which, however plausible they may appear in theory, could not be profitably carried out in practice. Without experience of the working of processes on the large scale it would be impossible to form even an approximate notion of the cost of production; and the ignorance of financial considerations which the scientific man has not unfrequently displayed has, I doubt not, in many cases caused the practical man to undervalue, or even deny, the advantage of the applications of science to manufacturing art. On the other hand, the practical man has often elicited the contempt of the scientific man, by propounding unphilosophical and sometimes absurd explanations of the processes which he conducts; and it must not be forgotten that the practical man, in spite of his purely practical pretensions, will generally and, according to my experience, always be found ready with an explanation of any phenomena he may observe: indeed, the practical man, paradoxical as it may seem, abounds in theories, often in the highest degree wild and visionary. From these considerations, the importance of the combination of scientific with practical knowledge in those who direct metallurgical establishments will more clearly appear.

Although the arguments which I have already advanced may

be regarded in some measure as a reply to the objection which, in a former part of this discourse, I anticipated might be urged against the utility of providing public instruction in metallurgy in this country, yet, from its *primâ facie* plausibility, it requires a more specific examination. The objection, it will be remembered, is, that as in Great Britain the practice of metallurgy has attained an unparalleled degree of development, and as this development has been effected in the absence of public instruction in metallurgy, such instruction must now be unnecessary.

By development I mean magnitude of production; but magnitude of production is no certain proof of correspondingly great skill. Let us consider first the special natural conditions under which the development in question has occurred. The largest and most important item of the metallurgical produce of Great Britain is iron; and it is precisely that item which, on comparing the amount of the metallurgical produce of Great Britain with that of other countries, makes the balance so great in favour of the former. Now, the ores of iron exist in extraordinary abundance throughout various districts of this country; and, what is very important in the consideration, the fuel necessary to the smelting of iron exists also in equal abundance, and, for the most part, in close proximity to the ores of iron. We have thus two conditions specially favourable to the production of cheap iron, abundant ore and fuel occurring together; and to these may be added the third condition of denseness of population, and, as a consequence, cheap labour. In no other country* do we find an equally favourable combination of circumstances for the production of cheap iron, not even in North America, where rich coal fields extend over a vast area, and the ores of iron exist in great profusion; for, generally, as the two do not occur together, the expense of carriage must necessarily be considerable. Moreover, as the country is as yet but comparatively thinly inhabited, the expense of labour is greater than in Great Britain. In respect, then, to the capability of the production of cheap iron our own country is at present unrivalled.

* Except, perhaps, Belgium.

But the mere smelting of iron, as compared with some other metallurgical operations, is a simple process. After the introduction of the proper admixture of ores, limestone, and fuel into the blast furnace, the only satisfactory indication of the working condition of the furnace is presented by the character of the slag as it flows out at the bottom. The quality of the metal produced from the same furnace, apparently under the same conditions, varies from time to time, even in two successive tappings.* Hence, as in the process of iron smelting there is but comparatively little opportunity for observation and interference on the part of the manager, and as under apparent identity of conditions the product may vary sensibly in quality, the operation itself cannot, in respect to the opportunity for the exercise of skill, compare with many other metallurgical processes.

But it must not be assumed that because this branch of industry has been generally carried on in this country by men who have not a scientific knowledge of the process, it would not with the aid of such knowledge have advanced to a much higher degree of perfection, whether as relates to economy of production or excellence of quality. Nor must it be assumed that because the production of iron (and in speaking of iron at the present time I mean pig-iron) appears to be a simple process, and because the men who conduct that process have frequently no scientific knowledge of it, science has done nothing towards the development of the smelting of iron in this country. Although we may not be able accurately to trace the history of improvement in many instances, yet we may be assured that the improvements which have from time to time been effected in the smelting of iron have not been altogether the result of accident or blind trial. The observation which I have just made respecting the production of pig-iron will also apply to the manufacture of bar or wrought iron, with the exception that in the latter case there is apparently much greater scope for the exercise of skill on the part of the workman and manager.

There are many problems of the highest interest in relation to the manufacture of iron and other metals at the solu-

* Even in the same tapping there may be several distinct varieties of metal.

tion of which we shall, most probably, only arrive by the aid of science. I have already alluded to the production of a slag termed "tap-cinder" in the conversion of pig or cast into bar or wrought iron. Of this slag thousands of tons have, until quite recently, been thrown away every year, notwithstanding it contains a larger quantity of iron than exists in the common argillaceous or most abundant ores of iron; and when it is introduced into the blast furnace with the ores of iron it tends in a special manner to deteriorate the quality of the iron produced. By the aid of analytical chemistry we are, I believe, enabled to determine why the use of this slag injures the quality of the iron; and thus, having a correct knowledge of the cause, we are in a better condition for devising means to counteract the defect than we should be if that cause were unknown to us.

We import annually a large quantity of foreign iron, especially for the manufacture of steel. In 1850 the importation amounted to 34,066 tons, the value of which may at least be estimated at 500,000*l.** Yet, I presume, if a method should be discovered by which British iron could be satisfactorily substituted for that amount of foreign iron, such a discovery would be regarded as advantageous to this country. Many attempts have been made to effect this substitution, but hitherto with only partial, though, I may add, increasing success. Particular varieties of iron are required for the production of particular qualities of steel; and we are still, in great measure, ignorant of the precise chemical differences between these varieties of iron. But without a knowledge of these differences, the determination of which will require the highest analytical skill of the chemist, we can only make blind attempts to solve the problem in question.

In the smelting of copper there are many points of considerable practical importance which are still very obscure, and which will certainly never be elucidated without the aid of science. Notwithstanding that copper smelting has been con-

* I make these numerical statements on the authority of my friend Mr. S. H. Blackwell, the author of the admirable statistical report on the iron trade in this country, contained in the Illustrated Catalogue of the Great Exhibition.

ducted in this country, during a long period, on a scale of unexampled magnitude, there is one point in the last part of the process,—the operation of "poling,"—which is even not yet clearly understood: I allude to the effect of "over-poling." Researches have, it is true, been made on this subject, but still, as it appears to me, without a decisive result. Again, the quality of the copper produced, not only in different smelting establishments, but in the same establishment, at different times, has been found very sensibly to vary in certain respects, especially of late, in spite of the efforts of the smelter to produce a metal of uniform quality. I know, indeed, that in some instances even smelters of great experience have taken special precautions to attain this end, but still not with constant success. Now it is clear, I think, that in such cases chemistry alone will enable us to determine the causes of this variation in quality, and without a knowledge of these causes the smelter can merely grope in the dark after means to obviate the defect. Already, I know that in some instances chemistry has rendered essential service of this kind. The variations in quality to which I have alluded are frequently not in the slightest degree indicated by the appearances of the metal, and only become manifest in the different processes of manufacture to which copper is subjected; as, for example, in rolling, hammering, and stamping, in dipping, and in the peculiar and sometimes very striking defects which it occasions in alloys. At a future period I shall enter at considerable length upon these points. In illustration of the variations in the quality of copper, I may mention the fact of the very different degree of corrosion by sea-water, observed especially during the last few years in the copper sheathing of the vessels of the navy.

The smelting of lead would also appear to present a promising field for the exercise of special scientific knowledge. In this country two methods of smelting are practised, and in both the loss of lead from volatilization is very considerable, amounting to ten per cent. or more. Accordingly, flues of great length, sometimes exceeding a mile, are constructed in order to effect as completely as possible the condensation of the lead smoke or fume. Other contrivances with the same view have been adopted; the smoke

has been caused to pass through water by means of powerful exhausting pumps, or water has been projected in a finely divided state, like rain, into chambers through which the smoke has been made to circulate; and other methods have also been tried with greater or less success, but all attended with no inconsiderable outlay. Now, as my friend, Mr. John Taylor junior, remarked to me, attention should rather be directed to the improvement of the smelting process itself, by effecting, if practicable, the separation of the lead at a temperature sufficiently low to prevent volatilization. But such an improvement, admitting its practicability, is far more likely to be made by the smelter who, with a practical knowledge of the process, combines the special scientific knowledge relating to lead smelting, than by the man who possesses only the former.

In tin-smelting, also, we meet with some interesting and important problems, which would seem to require the aid of chemistry for their solution. For example, in the manufacture of the best tin-plates, the tin required is of the best quality, and has, therefore, the highest price. Tin of inferior quality, and of less value by some pounds per ton, is unfit for that purpose. Chemistry will alone explain why one kind of tin is suitable, and another not; and when the causes of the difference between one quality of tin and another are known, it is not improbable that a method may be devised for converting tin of inferior into tin of superior quality, the difference of price between these qualities allowing a considerable margin, as manufacturers term it, for the expense of a process by which that conversion might be effected.

I might also, with equal propriety, allude to the manufacture of zinc, which, it is to be hoped, is not incapable of further improvement. There is at present a greater difference between the value of the ores of zinc and the zinc itself than in the case of any other metal.

Another very promising field for the exercise of science in relation to metallurgy is presented by the various metals which have not yet received any extensive practical application. Tungsten, for example, is in this category; it exists in nature in considerable abundance, and is frequently found associated with tin ore, from which it is separated as completely as practicable, and

thrown aside as worthless. It is true that attempts have recently been made to employ certain compounds of the metal in dyeing, as had previously been done thirty years ago; but these attempts have not, I believe, as yet been attended with any great success, or a demand for tungsten would have been created in consequence, which is not the case. Failures, however, should only have the effect of stimulating to further efforts in respect to the application of this metal, which, I confidently predict, will not much longer continue a comparatively worthless substance. Very substantial pecuniary emolument will, certainly, be the reward of the man who shall discover the mode of rendering tungsten extensively subservient to the arts. It is only a few years ago, that, in respect to commercial value, nickel occupied much the same position as tungsten at the present time; but now it is worth 8*s.* a pound, or about ten times more than copper. It is the whitening constituent of the alloy known as german silver. The silver-platers who practise the old method of plating by soldering, as well as those who deposit the silver by the agency of voltaic electricity, employ this alloy extensively, the advantage being that when the silver is worn from any part of an article, the alloy beneath sufficiently approximates to silver in whiteness as to deceive the eye respecting the wear. Some years ago, a compound of nickel, termed pottery nickel, was obtained in the manufacture of compounds of cobalt for the use of the potters, which was sold as low as three halfpence a pound, whereas it would now fetch about 3*s.* 6*d.*

Titanium is another metal, which, like tungsten, evidently exists in large quantity in nature, but which has hitherto only been applied to a very trifling extent in the arts, especially as a colouring ingredient in the manufacture of artificial teeth. I confess I am no believer in useless metals, and, therefore, with equal confidence repeat the prediction which I uttered in respect to the application of tungsten. Then, again, I may mention molybdenum, the only practical application of which is in analytical chemistry; and cerium and vanadium, which, if required, there is reason to believe might be obtained in some quantity. We must not disregard a metal on account of its rarity; for some of the rarest metals have of late been applied with great advantage. I may

mention, for instance, the native alloy of osmium and iridium, which only a very short time ago was confined to the laboratory of the scientific chemist. The alloy occurs in small grains, so intensely hard that the hardest file will not make an impression upon them. The tips of the so-called gold pens are made of these grains; but for this purpose only the larger grains can be employed. The demand for these grains in the pen-manufacture is now considerable, and the price ranges between six and eight pounds an ounce. Iridium has also been applied as a black pigment in painting on porcelain. In intensity of blackness it is said to exceed all other black porcelain colours, which by the side of the iridium-black appear more or less grey. It is only within the last few years that uranium has been employed to produce the delicate canary yellow colour in glass with which we are all familiar; but the demand for that metal is at present so considerable that there is a difficulty in supplying it. Another similar instance of successful recent application is afforded by cadmium, which occurs in small proportion in certain ores of zinc. This metal in combination with sulphur constitutes the finest and most durable opaque yellow colour with which the artist is acquainted. The metal itself has also been used in conjunction with mercury and tin for filling teeth; but certain disadvantages arising from its use have caused it to be abandoned for that purpose. I have expressly been somewhat minute in detailing the preceding instances of the successful application of metals not long since regarded as valueless to the arts, in order to excite and stimulate efforts to promote the application of the other metals which I have mentioned as still without useful application; and, moreover, to encourage the hope of success by showing how extensive a field for application is presented in the various arts.

Having now, as I conceive, sufficiently established the importance of special scientific knowledge to the metallurgist, I proceed to describe particularly the kind of instruction which I propose to impart in this institution. That instruction will be conveyed in two ways, by lectures, and by practical demonstrations in the metallurgical laboratory. The student, however, before entering upon the study of metallurgy, will be required to give satisfactory evidence of his possessing a competent knowledge of general chemistry, theoretical and practical.

In the lectures, a minute description will be given of the characters and properties of the various metals, which are properly the subject of metallurgical inquiry, and of such of their compounds as are of special metallurgical importance; for example, their combinations with oxygen, sulphur, phosphorus, silicon, carbon, &c. Their ores will next be treated of, and special attention will be devoted to the consideration of certain matters, the presence of which, even in small quantity, is liable in a marked degree to affect the quality of the metal extracted. The processes of separating the metals from their ores as prepared by the miner will be fully described; and this description will comprise ample details respecting the apparatus and mechanical appliances generally which are required in metallurgical operations, as furnaces, crucibles, blowing-engines, and rolling-mills. The various materials employed in the construction of furnaces, as fire-clay and fire-stones, will be carefully passed in review, together with the kinds of fuel used. The adventitious products which are obtained in any metallurgical processes, as the various kinds of slag or scoria, and a knowledge of which may frequently be of great practical importance, will be discussed at considerable length. The cost of production, and the more important applications of the metals, especially as alloys, and to electro-plating, will receive prominent attention, as will also the theories of the various processes described.

In the laboratory, practical instruction in assaying will be given, and in those special departments of analytical chemistry which have a particular and important bearing upon any given metallurgical process. The various methods of assaying in the case of any given metal will be compared by experiment. The student will also be specially instructed in the use of that invaluable instrument, the blow-pipe, which is not only constantly employed in the discrimination of minerals, but may occasionally be advantageously used in quantitative assaying. To those who may travel in distant parts of the world, the use of the blow-pipe cannot be too strongly recommended, as it frequently affords the readiest and most accurate means of determining the nature of ores; added to which, its extreme portability is a very important consideration to the traveller.

Moreover, I shall endeavour to adapt the source of study in the laboratory to the special department of metallurgy in which it is most important that the student should become proficient. Thus, in the case of a student desiring to acquire the special scientific knowledge relating to lead-smelting, I should direct his attention to that part of analytical chemistry which would enable him to ascertain the precise composition of the ores of lead and of the adventitious products obtained in lead-smelting, as lead-slags and lead-fume; and I should also require him to demonstrate by experiment, as far as practicable in the laboratory, the re-actions which take place in the process of smelting.

The lectures will be illustrated by specimens, diagrams, and models; and I may remark that in metallurgical lectures the illustrations presented to the student are of great practical value. It is essential that he should see, and examine carefully for himself, the specimens which illustrate metallurgical processes. No description, however accurate and minute, could in many cases convey to his mind precise notions of the external characters of substances with which it is important for him to be familiar. In the process of poling copper, for example, small portions of metal are taken out of the furnace at short intervals, until it presents certain specific appearances which indicate the condition of the copper, and the period when it is necessary to arrest the operation. In the smelting of iron also, certain appearances of the slag furnish characteristic indications of the working condition of the furnace. But these appearances must be seen to be understood.

The museum, I am happy to state, already possesses a metallurgical collection of considerable value, and which will, I trust, at no distant period become one of the most perfect in Europe. The illustrations of the principal metallurgical processes of this country as the smelting of iron, copper, lead, and tin, and the manufacture of steel, are very satisfactory. The foreign collection is rapidly increasing, and will be found of great practical utility to those who direct metallurgical establishments. Indeed I know that many gentlemen connected with such establishments have visited the museum, and expressed their appreciation of the important practical bearing, especially of the foreign collection.

I may be permitted to add, that in addition to the collection arranged in the museum, I shall be able to illustrate the lectures by an extensive series of specimens which I have myself been engaged in forming during the last twelve years. This collection contains numerous examples of the defects which occur from time to time in the working of certain metals, and which frequently depend upon the presence of foreign bodies in minute proportion which have escaped detection by the smelter.

In regard to models, the metallurgical department of the museum is also in a promising condition. The metallurgist on visiting the model-room will observe that the metallurgical models have not been constructed for the purpose of amusing the casual spectator, but of instructing the student. Each will be found to possess some special feature of interest in relation to practice. The collection comprises models of various furnaces, of a blast-engine, a very beautiful and complete model of the steel works of Messrs. Naylor, Vickers, and Co., munificently presented by them to the Institution, &c.; and to these may be added apparatus used in assaying, including that of Gay-Lussac for assaying silver, (now adopted at most of the continental mints), crucibles, and other metallurgical instruments.

Having explained the nature of the instruction which I propose to impart in this Institution, I may in a few words state what I do not pretend to teach. I do not pretend to teach practical smelting, or that knowledge which can only properly be acquired by experience in the manufactory. But I do hope to be able to communicate information to the student which he will be able to apply with great advantage when, at a future period, he may be engaged in the practice of metallurgy on the great scale, by which he will be prevented from the commission of blunders such as I have mentioned, and be placed in the best possible condition for effecting some of the many desirable improvements in metallurgical processes.

It will doubtless have been remarked, throughout this introductory discourse, that I have considered the subject of instruction in metallurgy exclusively in relation to practice, or in other words, to speak plainly, in a pounds-shillings-and-pence point of view. I have done so for special reasons. This Institution

professes to be a School of Mines, the chief object of which should be to render science subservient to manufacturing art; or, what is equivalent, disguise it by words as we may, to make science remunerative. Our practical metallurgists may be men of large hearts and philanthropic views respecting the application of science to the benefit of man; but if we wish to urge upon them the importance of combining scientific with practical knowledge, we must demonstrate that that combination will be of pecuniary advantage to themselves. What care they, if deficient of a taste for science, about any novel and ingenious application, if it cannot be made a source of profit? What inducement can they have for investing capital to carry into practice an invention, however beautiful and attractive in a scientific point of view, apart from the consideration of gain? If we address men of business on the applications of science, we must take the business view of the matter; and, as from the very nature of my subject, I must be supposed to be speaking to men who either are or may become interested in metallurgical establishments, I have felt it incumbent upon me to speak as I have done.

But let it not be imagined that the study of metallurgy has no attractions for the man of science: so far from that being true, it is a study abounding in problems of great scientific interest, and affording ample scope for the exercise of the highest powers of research; and while the lover of abstract science will discover in it much to reward his attention, to the man who delights in the application of science to the useful purposes of life it presents peculiar charms. To the antiquarian also it will often be found to render good service; for, as the working of metals dates from the earliest period of man's history, the remains of ancient furnaces and the products of ancient metallurgical skill not unfrequently become the subjects of archæological inquiry. It is interesting, moreover, to trace the history of the metallurgic art, and to note how the rude and laborious processes of former times have gradually acquired the marvellous development which we observe in Europe at the present day. In order to form a vivid conception of this progress, we have only to witness the Hindoos toiling laboriously

at their bellows made of skin, to extract a few pounds of iron from their little furnace, scarcely larger than a chimney-pot, and then to direct our attention to the gigantic blast-furnace of modern times, urged by a blast-engine, requiring for its movement the equivalent in steam-power of a hundred horses, and yielding upwards of two hundred tons of iron a week.

As the character of this discourse is essentially practical, I should wish, before concluding, to guard myself from the imputation of undervaluing knowledge, whether literary or scientific, which appears to have no direct practical bearing. It would be furthest from my intention to utter a word in disparagement either of polite literature or abstract science. In this utilitarian age there is a danger of forgetting that the human mind is destined for a higher purpose than that of being wholly absorbed in the material realities of life. There is no incompatibility between the pursuits which elevate, refine, and delight our taste, and those which we are called upon to follow, as well for our personal advantage as for the benefit of our race. In contemplating the marvellous triumphs of human ingenuity at the present epoch of unexampled progress, we should be careful not to depreciate unjustly the character of the education which we received in youth; and we should bear in mind that, although that education may not have made us acquainted with natural objects and phenomena to the extent we might desire, it has yet been the means of subjecting the various faculties of our minds to a most salutary and invigorating discipline.

In conclusion, permit me to impress upon your attention that the chief object of the present discourse is to show the importance of special scientific knowledge to the metallurgist; and the proof, it will be borne in mind, rests chiefly upon the instances adduced in which the want of that knowledge has been shown to have occasioned pecuniary loss. But if the proof be admitted to be satisfactory, it will then follow that the diffusion of such knowledge by public instruction must be of public advantage; for in proportion to the success with which the metallurgic art is practised in this country will the interests of the whole population directly or indirectly in no inconsiderable degree be promoted.

GOVERNMENT SCHOOL OF MINES, AND OF SCIENCE APPLIED TO THE ARTS.

MUSEUM OF PRACTICAL GEOLOGY.

THE importance of the Mineral Wealth of the United Kingdom far exceeds that of any other European State, and furnishes four-ninths of the raw mineral produce derived from all Europe. Although the annual value of the mineral produce of this kingdom amounts to £24,000,000, and the capital and labour employed in its extraction and application represent a much larger sum, no school, having for its especial object the instruction of persons engaged in mining operations, has yet been established in the United Kingdom.

Mining Schools have long existed in France, Russia, Prussia, Saxony, Austria, Spain, Sweden, Denmark, and other countries even less connected with mining, and their practical value is recognized by the fact, that the respective Governments of these States have found it necessary to develope still further the educational resources of such institutions. The want of similar establishments in this country has long been felt in mining districts, and has been expressed both in Parliament and in memorials addressed to the Government. In the Report of the Committee of the House of Lords, (1849), the Committee observe, that, "among those best qualified to speak "upon this point, a want appears to be felt of facilities for acquiring mining "education such as are provided by the mining schools and colleges estab- "lished in the principal mining districts of the continent, apparently with "the most beneficial effects." Memorials have been presented from the principal mining districts of the kingdom, urging this want, and indicating the Museum of Practical Geology as the proper institution to be converted into a mining school. In consequence of these representations, and of the enlargement of the Museum, the Government have determined to apply the resources of the Institution to public instruction in Mining, and in the applications of science to the arts.

The Collections of the Museum are now made available for educational purposes. The laboratories and working rooms of the several departments are so arranged and organized, that systematic studies in Chemistry, Metallurgy, Geology, Palæontology, Physics, Mineralogy, and Mining, are given under the direction of the officers of the respective departments. The Museum itself is of an essentially practical character, and was primarily

intended to bring science to bear on geology in its application to the useful purposes of life; its officers were selected with a view to carry out the educational character of the institution, recognized shortly after its formation by an official letter of the Chief Commissioner of Her Majesty's Woods, and sanctioned by the Lords of the Treasury.

The following is a list of the Officers entrusted with the courses of instruction:—

PRESIDENT.—Sir HENRY T. DE LA BECHE, C.B., F.R.S.

CHEMISTRY, applied to the Arts and Agriculture	*Lyon Playfair*, Ph. D., F.R.S.
NATURAL HISTORY, applied to Geology and the Arts	*Edward Forbes*, F.R.S.
MECHANICAL SCIENCE, with its application to Mining	*Robert Hunt*, Keeper of Mining Records.
METALLURGY, with its special applications	*John Percy*, M.D., F.R.S.
GEOLOGY, and its practical applications	*A. C. Ramsay*, F.R.S.
MINING and MINERALOGY	*Warington W. Smyth*, M.A., F.G.S.

The educational course of this School differs essentially from that given in colleges where general education is the primary object. Although it is intended to give general instruction in science to those who may require elementary knowledge, still, the chief object of the institution (to which everything else is made subsidiary) is to give a practical direction to the course of study, so as to enable the student to enter with advantage upon the actual practice of mining, or of the arts which he may be called upon to conduct. It may therefore be desirable to call attention to the peculiar features of the institution, and to the courses of lectures given by the respective professors.

THE MUSEUM.

The Geological Survey of the United Kingdom being carried on in connexion with the Museum has afforded great facilities for making complete collections illustrative of the applications of geology to the useful purposes of life. These collections contain an extensive series of rocks stratigraphically arranged, with reference to their mode of accumulation, and the subsequent action of various causes upon them; of fossils classed in the order of geological time; of specimens illustrative of the ores of the useful metals, of their mode of occurrence, and of the methods of preparing them for smelting; of mineral substances used for constructing public works and buildings, and of those employed for ornamental purposes, or for the useful arts in connexion with chemical or metallurgical manufactures. The processes of converting these raw materials into industrial products are carefully exhibited, and illustrations of the finished products are also displayed. The various arts connected with the mineral resources of the country are illustrated by specimens showing varieties or peculiar excellencies of manufacture.

Models of Mines, Mining Tools, and Working Models of Mining Machinery are collected, with the view of exhibiting the various modes of

working carried on in different districts. The Museum is open to the public for the first three days of the week, the remaining days being reserved for study.

Geological Surveys.

The Geological Surveys of the United Kingdom are carried on under the general direction of Sir H. T. De la Beche, and their central office is at the Museum. In this office the maps and sections are prepared and deposited. The field surveys are carried on in the localities under examination for the time being, and instruction in the field in the various departments of Geological Surveying is given by the Mining, the Geological, and the Palæontological Professors.

Office of Mining Records.

This office, superintended by Mr. Robert Hunt, is established for the preservation of Mining Records. The absence of these needful documents was found to be the cause of much waste, either in attempts to work in localities where there is little prospect of success, or where from a want of proper knowledge of the old workings much useless expenditure is incurred. Numerous copies of plans and sections of mines, and many important statistical mining details, are deposited in this office, and are made available for the instruction of students.

Laboratories.

Two laboratories, one for general, practical, and analytical Chemistry, under Dr. Lyon Playfair, the other for Metallurgy and Assaying, under Dr. Percy, are established in the Museum. Students are, under certain regulations, admitted into the Laboratories for the purpose of receiving instruction in the analysis of minerals and ores, and of the methods used in applying them to useful purposes in the arts.

Unless the student has already become acquainted with Practical Chemistry, it is requisite to pass through the Chemical laboratory before entering that for Metallurgy, as the latter requires previous chemical knowledge before its study can be usefully entered upon.

Palæontological Department.

As the relative age and sequence of geological formations are, to a great extent, determined by the fossils they contain, it has been found necessary, in the prosecution of the Geological Survey, to attach a department of Natural History, under the direction of Professor E. Forbes, where the organic remains contained in the sedimentary rocks of the British Islands may be examined and preserved. Extensive collections of these fossils are now made and arranged, and are used for the instruction of students.

Regulations as to Admission.

Persons desirous of entering as matriculated students, with a view of eventually obtaining the diploma of the Institution, must be at least 16 years of age, and will be required to bring certificates or other evidence of their having received a sufficient preliminary education. They shall pay *thirty pounds* in one sum on entrance, or two annual payments of *twenty pounds* each, for admission to all the courses of lectures extending over two years, and field instructions, according to the regulations of the Institution, and shall have the privilege of studying in the Museum and Library.

The charge for instruction in the laboratories (which is not included in the above) is *thirty pounds* for the session of ten months, or *fifteen pounds* for the term of five months. The laboratories are open to [illegible] as matriculated [illegible]

[illegible], on a charge of *five pounds*

Exhibitions.

His Royal Highness Prince Albert has intimated that His Royal Highness the Prince of Wales has grantedto the School of Mines two annual exhibitions of thirty pounds each, to be held for two years, and to be called "The Duke of Cornwall's Exhibitions." These will be competed for by examinations of the matriculated students, at the termination of their first year's course.

Particulars respecting the times of Lectures, and all other information, may be obtained by application to Mr. Trenham Reeks, at the Museum of Practical Geology, 28, Jermyn Street.

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND OF THE

MUSEUM OF PRACTICAL GEOLOGY.

THE

SOUTH STAFFORDSHIRE COAL-FIELD.

BY

J. BEETE JUKES, M.A. CAMB., F.R.S., &c.,

LOCAL DIRECTOR OF THE GEOLOGICAL SURVEY OF IRELAND.

SECOND EDITION.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

LONDON:

PRINTED FOR HER MAJESTY'S STATIONERY OFFICE.

PUBLISHED BY

LONGMAN, GREEN, LONGMAN, AND ROBERTS.

1859.

LONDON : PRINTED BY GEORGE E. EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.

NOTICE.

THE Memoir on the Geology of the South Staffordshire Coal-field, by Mr. J. Beete Jukes, having been long out of print, a second edition was much called for, and it gives me satisfaction to perceive that a work which has proved so useful to the mining proprietors of that district should have undergone material improvements by Mr. Jukes, who, having himself re-examined the tract, has availed himself of all the information afforded by new workings, &c.

The statistical note by Mr. R. Hunt on the amount of coal and iron raised in South Staffordshire has been brought up to the year 1858.

RODERICK I. MURCHISON,
Director-General.

Geological Survey Office,
Jermyn Street, London.

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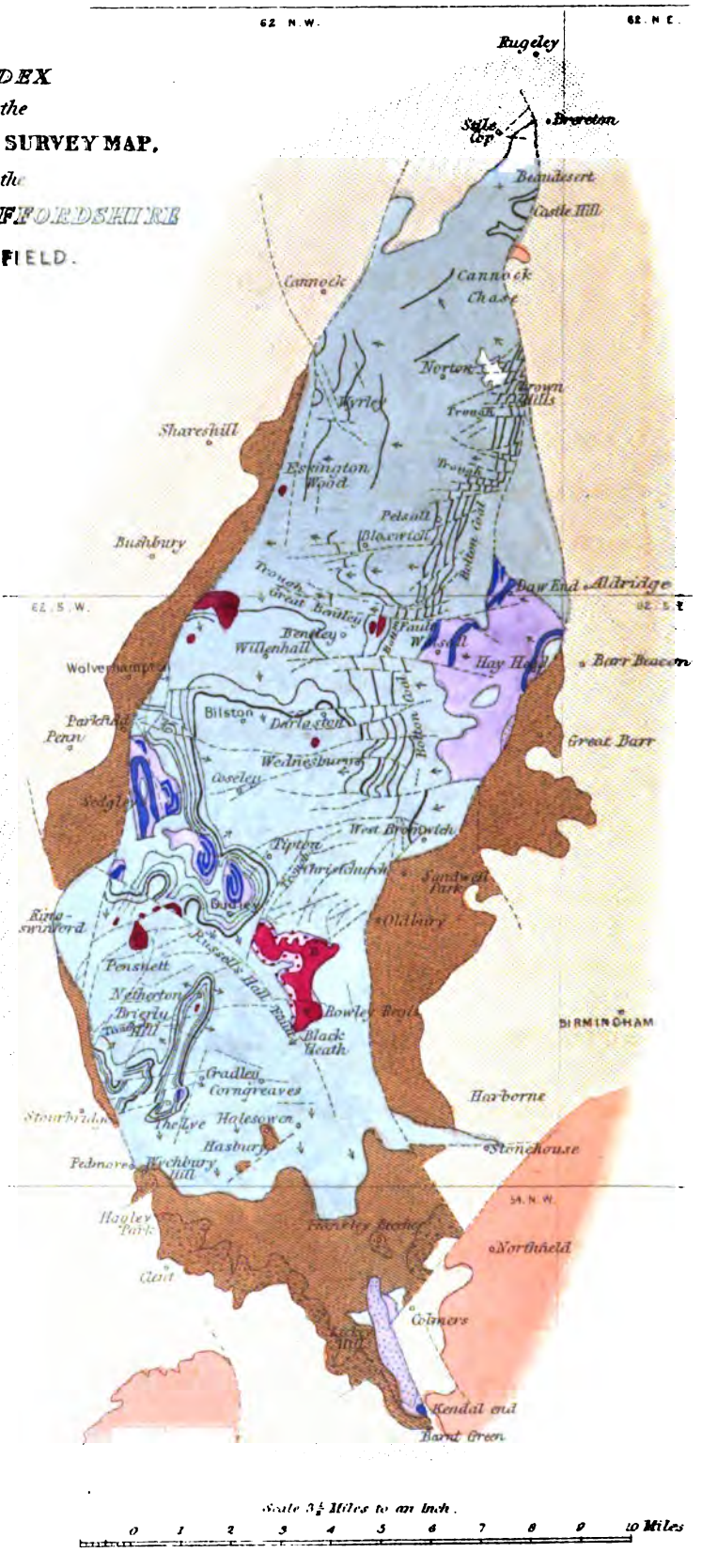
of the
GEOLOGICAL SURVEY MAP,
of the
SOUTH STAFFORDSHIRE
COAL FIELD.



Coal Beds.

Lines of Fault

New Red Marl.

New Red Sandstone.

Lower Red or Permian Sandstone & Trappoid Breccia in d°

Coal Measures

Upper Silurian Shale and Limestone.

Llandovery Sandstone

Basalt and Greenstone

Scale 3½ Miles to an Inch.

0 1 2 3 4 5 6 7 8 9 10 Miles

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The Maps to which reference is made in this Memoir are those of the Ordnance Survey of Great Britain, coloured Geologically by the Geological Survey, and consist of the following Sheets of those Maps, of which new and revised editions have been lately published :—

Sheet 54. N.W. Quarter Sheet.
— 62. N.W. N.E., S.W., and S.E. Quarter Sheets.
— 72. S.W. and S.E. Quarter Sheets.

The Horizontal Sections are Sheets 23, 24, 25, and 45, containing the following Sections :—

SHEET 23, No. 1, N. and S. from Bellbroughton, over Clent Hills, through Dudley, Bentley, and Brereton to Rugeley. No. 4. E. and W. across Brereton Colliery district. No. 5, E.S.E. and W.N.W. through Wyrley and Brown Hills.

SHEET 24, No. 2, N. and S. from Lappal, by Rowley, Dudley, and Sedgley to Compton, near Wolverhampton. No. 3, N. and S. through Hagley Park, Brierley Hill, Barrow Hill, Turner's Hill, and Lidget Hill. No. 6, E. and W. through Sedgley, Darlaston, and Walsall to Barr Beacon.

SHEET 25, No. 7, E. and W. through Kingswinford, Dudley, and Westbromwich. No. 8, E. and W. through Wordesley, Brierley Hill, and Rowley to Langley Mill. No. 9, E. and W. through Stourbridge, Cradley, the Hawn, Mucklow Hill, and the Quinton. No. 10, N. and S. through Frankly, Beeches, Hasbury, the Hawn, to the Old Lion Colliery.

SHEET 45, part of No. 1, E. and W. through Essington Wood and Pelsall, continued to the Coalbrookdale Coal-field.

The Vertical Sections referred to are Sheets 16, 17, 18, and 26, containing the following 52 pit sections, on the scale of 40 feet to the inch :—

SHEET 16. No. 1. Brereton, near Rugeley.
No. 2. Hammerwich, Cannock Chase.
No. 3. Wyrley district.
No. 4. Aldridge trial pits.
No. 5. Harrison's water engine, Brown Hills.
No. 6. Bentley district.
No. 7. Ryecroft, near Walsall.
No. 8. Ettingshall Lodge, near Wolverhampton.
No. 9. Chillington colliery, near Wolverhampton.
No. 10. Two pits at Priestfield, near Wolverhampton.
No. 11. Trentham colliery, near Willenhall.
No. 12. Tipton Green colliery.
No. 13. Bagnall's Limestone pits, Dudley Port.

SHEET 17. No. 14. Burnt Tree and Coneygree pits, Dudley.
No. 15. Great Bridge colliery, Westbromwich.
No. 16. Lyng colliery, Westbromwich.
No. 17. Heath pits (with plan of headings), Westbromwich.
No. 18. Brichyfield colliery, near Oldbury.
No. 19. Oakfarm, near Himley.
No. 20. Parkfield, near Wolverhampton.
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SHEET 18. No. 23. Barrow Hill and Graveyard pits, near Dudley.
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No. 25. Old Lion colliery, Cradley Heath.
No. 26. Blackheath colliery, S. of Rowley Regis.
No. 27. Boring at " Ruck of Stones," Smethwick.
No. 28. Bullock farm pits, Westbromwich.
No. 29. Dudley Brothers colliery, near Bloxwich.
No. 30. Monmore colliery, near Willenhall.
No. 31. Shut End colliery, near Kingswinford.
No. 32. Walling pits, between Bilston and Wolverhampton.
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No. 41. Brown Hills, Cathedral pits, Mr. Harrison's.
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No. 44. Coppy Hall colliery, Walsall Wood.
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No. 47. Rowley, Ramrod Hall pits.
No. 48. Himley, Round Hill pits.
No. 49. New Bromley Lane, near Kingswinford.
No. 50. Goldthorn Hill waterworks, near Wolverhampton.
No. 51. Highfields, near Bilston.
No. 52. Tividale, near Dudley.

These Maps and Sections are to be procured at the MUSEUM OF PRACTICAL GEOLOGY, Jermyn Street, London, or from Messrs. LONGMAN & Co., Paternoster Row, London.

PREFACE TO THE SECOND EDITION.

It was not till the month of October 1858 that I could make arrangements for such a re-examination of the South Staffordshire Coal-field as should enable me to bring out a second edition of this Memoir. Many new mines and cuttings of different kinds having been opened during the preceding nine years, this re-examination, brief as it was, afforded fresh information on some points that had previously been obscure.

My colleagues, Messrs. Hull and Howell, under the direction of Professor Ramsay, have completed the examination of the details of the New Red Sandstone of the Midland counties, and Professor Ramsay has now contributed (pp. 3 to 8) an account of their results.

I have added also to the description of the Permian rocks an abstract of Professor Ramsay's remarkable speculations on the origin of the large angular blocks in the Permian breccia (pp. 13 to 15).

In the coal-field, the new pits at Essington and those on Cannock Chase gave additional data for the co-relation of the Wyrley and Essington district with the remainder of the field. The identity of the separated coals of Wyrley and Essington, (from the Old Robins coal down to the Bentley Hay coal), with those which, in the central part of the coal-field, unite to produce the Thick coal, is thus put beyond doubt. There was, indeed, no doubt on my own mind of this fact even ten years ago. A diagram, illustrative of the method of this expansion of the measures and separation of the coals, is now added to the general description of the Coal-measures.

An important change has been made, both in the Memoir and in the latest edition of the maps and sections, as regards the

classification of certain red clays and sandstones which occur at Walsall Wood, Essington Wood, and at other localities about or within the coal-field. These were at first supposed to belong to the New Red Sandstone, afterwards were believed to be Permian, but are now decided to be true Coal-measures. I find in my own manuscript notes, made during the survey of the coal-field, the strongest expressions of opinion that these were in reality Coal-measures; but as that conclusion involved practical consequences which might, if erroneous, have led some persons into fruitless expenditure, it was thought safer to colour them as Permian until more evidence could be procured.

The opinion that they are upper Coal-measures, however, is now so strongly supported by my colleagues, and by several resident gentlemen of practical experience, and seems so far confirmed by the facts learnt in sinking the pits at Coppy Hall by the Rev. Baily Williams, that there is no longer any necessity for reserve in expressing the opinion, or for hesitation in altering the colouring of the maps and sections accordingly. It adds several square miles to the area of the northern part of the coal-field.

The driving of the tunnel beneath the Rowley Hills, which by a rather unfortunate misnomer is called the Netherton tunnel, added somewhat more of precision to our ideas respecting the "position and lie," of the Rowley basalt than we previously possessed. I regret that I was not aware till it was completed that this so-called Netherton tunnel was being driven through the base of the Rowley Hills, and thus was not led to visit it during the operation. This and the analyses of two specimens of the trap rocks by Mr. Henry, of London, has enabled me to give a little more complete account of the igneous rocks of the district. An equally good analysis of the "green rock" or "greenstone" of the district is still a desideratum.

I regret that an injustice was done in the first edition of this Memoir to the memory of Mr. Keir, whose excellent account of the coal-field, so far as it was known in his day, was published in Shaw's History of Staffordshire. Not only were his labours altogether ignored, but some of his materials were used at second hand without any acknowledgment of the true source whence they

were derived. I need hardly say that this injustice was unintentional, and arose from forgetfulness, chiefly the result of the circumstances under which the Memoir was composed. The documentary materials for it were collected from different persons at different times, and were reduced to order at intervals in different parts of England, Wales, and Ireland. Anything like research into books was almost necessarily precluded, and the attention was fixed on the materials which were at hand, and which could be carried about in the portmanteau.

This absence of research into the labours of previous or contemporaneous writers is a defect which it is difficult for those to avoid who are almost constantly engaged in field work and debarred from access to libraries, except at rare and short intervals. It has been indeed hitherto sufficiently difficult for the officers of the Geological Survey to find time to give any written account even of their own labours, the results of which have been chiefly published in the form of maps and sections.

In the following Memoir the attention is confined solely to the facts observed in the district; from some questions that have been put to me, however, I believe that a few preliminary words respecting the relation of the Carboniferous rocks of South Staffordshire to those of the neighbouring districts will not be out of place.

I have been asked especially as to the reason of the absence of the groups of rock known as Millstone grit, Carboniferous limestone, and Old Red sandstone, between the Coal-measures and the Upper Silurian rocks of South Staffordshire.

If we proceed from the South Staffordshire to the North Staffordshire coal-field, a distance of only 20 or 25 miles, we find a vast difference in the constitution of the Carboniferous rocks. In South Staffordshire the Carboniferous rocks consist of Coal-measures only, the maximum thickness of which does not seem ever to have much exceeded 1,000 feet. In North Staffordshire these beds are far more numerous, and attain an aggregate thickness four or five times greater. Thick masses of sandstone occur about their base, which are grouped together under the name of the Millstone grit. Below this, as we go towards Derbyshire, we find thick beds of black shale, in some places

interstratified with thin limestones, and from underneath these comes out an assemblage of beds of pure limestone several hundred feet in thickness, forming all the beautiful hill country that spreads from Dovedale to Matlock and thence to Castleton and Buxton. This group of limestone is called the Mountain or Carboniferous Limestone, and the black shale between it and the Millstone grit is known as the Upper Limestone Shale.

The Carboniferous Limestone, either simple as a group of beds of pure limestone or complicated by being more or less interstratified with shales and sandstones, extends from Derbyshire to the borders of Scotland with a mean thickness of probably 2,000 feet at least; it re-appears as a simple limestone in North Wales, in Flintshire, and Denbighshire, and in the same form in South Wales and the adjacent parts of England, varying in thickness from 500 to 1,000 feet. The Coal-measures of the South Welsh coal-field are certainly 7,000 feet, even if they are not in some places 12,000 feet, in aggregate thickness, and have a thick group of sandstone beds at the base, which may be called the Millstone Grit, as well as another higher up, known as Pennant Grit. But from underneath the Carboniferous Limestone, which forms the thick enamelled lining, as it were, of the basins of the South Welsh and Forest of Dean coal-fields, there rises on all sides a great group of red and brown sandstones and red marls, known as the Old Red Sandstone. This Old Red Sandstone forms whole mountains of 2,700 feet in altitude (as the Vans of Brecon), and cannot in some places have a less aggregate thickness than about 10,000 feet.

Now these vast formations of Old Red Sandstone and Carboniferous limestone (to say nothing of the lower part of the Coal-measure series or Millstone grit) are altogether absent in South Staffordshire, neither is there the slightest reason for supposing that any part of them ever existed in that district. For not only are they absent in South Staffordshire, but there is a band of country running E. and W. across England from Leicestershire, through Warwickshire, South Staffordshire, North Shropshire, into Montgomeryshire, along which they are equally deficient.

In Leicestershire, the Carboniferous limestone, thinning out

from Derbyshire, ends on the north side of Charnwood Forest, while the Coal-measures overlap it and rest upon the Cambrian rocks. In Warwickshire no Carboniferous limestone makes its appearance. In South Staffordshire the Coal-measures rest directly upon Upper Silurian rocks. In the Coalbrookdale coal-field the Coal-measures resting towards the south on the Old Red Sandstone, overlap its termination towards the north, and repose upon Upper Silurian rocks, and further west, towards Church Stretton and the Breiddens, upon Lower Silurian and Cambrian rocks. Thin scraps of Carboniferous limestone, indeed, show themselves about Lillieshall, as if spreading just so far from Derbyshire, and also at the Clee Hills, as if dying out from South Wales, and the Old Red Sandstone likewise stretches from the latter direction, but thins out and terminates before reaching the Severn. It is clear then that the absence of the Old Red Sandstone and Carboniferous limestone from the narrow band of country before indicated, is due to causes operating during the deposition of those formations. They each died away and terminated as they approached it both from the north and the south.

Now these formations were deposited under water, the Carboniferous limestone certainly under the sea, as is shown by its being almost entirely made up of the remains of marine animals, it seems natural then to suppose that the area towards which they thus both thin out and terminate was not under water, but formed dry land. It is, in fact, almost certain, that whilst the sea flowed deep over the remainder of that space where England and Wales now exist, during the periods when the great formations of Old Red Sandstone and Carboniferous limestone were in course of deposition, a narrow promontory, or an island, or a group of closely connected islands ran in an east and west line across the district before pointed out. This land, however, must itself have been depressed either wholly or in part while the Coal-measures were being deposited, and as it slowly sank beneath the water, sheet after sheet of Coal-meausres extended over it, till, perhaps, the whole neighbourhood was finally buried under one wide-spread subaqueous Coal-measure plain. Since that time it has not only been lifted up again, but broken, dislocated, and contorted by forces of dis-

interstratified with thin limestones, and from underneath these comes out an assemblage of beds of pure limestone several hundred feet in thickness, forming all the beautiful hill country that spreads from Dovedale to Matlock and thence to Castleton and Buxton. This group of limestone is called the Mountain or Carboniferous Limestone, and the black shale between it and the Millstone grit is known as the Upper Limestone Shale.

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Now these formations were deposited under water, the Carboniferous limestone certainly under the sea, as is shown by its being almost entirely made up of the remains of marine animals, it seems natural then to suppose that the area towards which they thus both thin out and terminate was not under water, but formed dry land. It is, in fact, almost certain, that whilst the sea flowed deep over the remainder of that space where England and Wales now exist, during the periods when the great formations of Old Red Sandstone and Carboniferous limestone were in course of deposition, a narrow promontory, or an island, or a group of closely connected islands ran in an east and west line across the district before pointed out. This land, however, must itself have been depressed either wholly or in part while the Coal-measures were being deposited, and as it slowly sank beneath the water, sheet after sheet of Coal-meausres extended over it, till, perhaps, the whole neighbourhood was finally buried under one wide-spread subaqueous Coal-measure plain. Since that time it has not only been lifted up again, but broken, dislocated, and contorted by forces of dis-

interstratified with thin limestones, and from underneath these comes out an assemblage of beds of pure limestone several hundred feet in thickness, forming all the beautiful hill country that spreads from Dovedale to Matlock and thence to Castleton and Buxton. This group of limestone is called the Mountain or Carboniferous Limestone, and the black shale between it and the Millstone grit is known as the Upper Limestone Shale.

The Carboniferous Limestone, either simple as a group of beds of pure limestone or complicated by being more or less interstratified with shales and sandstones, extends from Derbyshire to the borders of Scotland with a mean thickness of probably 2,000 feet at least; it re-appears as a simple limestone in North Wales, in Flintshire, and Denbighshire, and in the same form in South Wales and the adjacent parts of England, varying in thickness from 500 to 1,000 feet. The Coal-measures of the South Welsh coal-field are certainly 7,000 feet, even if they are not in some places 12,000 feet, in aggregate thickness, and have a thick group of sandstone beds at the base, which may be called the Millstone Grit, as well as another higher up, known as Pennant Grit. But from underneath the Carboniferous Limestone, which forms the thick enamelled lining, as it were, of the basins of the South Welsh and Forest of Dean coal-fields, there rises on all sides a great group of red and brown sandstones and red marls, known as the Old Red Sandstone. This Old Red Sandstone forms whole mountains of 2,700 feet in altitude (as the Vans of Brecon), and cannot in some places have a less aggregate thickness than about 10,000 feet.

Now these vast formations of Old Red Sandstone and Carboniferous limestone (to say nothing of the lower part of the Coal-measure series or Millstone grit) are altogether absent in South Staffordshire, neither is there the slightest reason for supposing that any part of them ever existed in that district. For not only are they absent in South Staffordshire, but there is a band of country running E. and W. across England from Leicestershire, through Warwickshire, South Staffordshire, North Shropshire, into Montgomeryshire, along which they are equally deficient.

In Leicestershire, the Carboniferous limestone, thinning out

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turbance acting from below, and worn and eroded by denuding agencies acting from above; fresh formations have been deposited over it, and these also with the subjacent rocks broken and again denuded, till all likeness of its former state has been utterly destroyed, and its former condition left to be guessed at solely by deductions drawn from the relations which can be traced between the formations of which it is composed.

J. Beete Jukes.

51, Stephen's Green, Dublin,
6th September 1859.

ON THE GEOLOGY OF THE SOUTH STAFFORDSHIRE COAL-FIELD.

By J. BEETE JUKES, M.A. Camb., F.R.S., &c.

LOCAL DIRECTOR OF THE GEOLOGICAL SURVEY OF IRELAND.

CHAPTER I.

Physical Geography of the District.

The district to be described in the following pages is situated chiefly in the southern division of the county of Stafford, but extends into part of the northern division of that county, as well as into the adjacent counties of Worcester,* Warwick, and Salop.

The most important portion of the district is the coal-field, which would be included within a line drawn from Brereton near Rugeley, through Cannock to Wolverhampton, thence through Kingswinford to Stourbridge, and from that to the hills known as the Bromsgrove Lickey, and thence by Harborne near Birmingham, through Aldridge, back again to Brereton.

The distance north and south from Brereton to the south end of the Bromsgrove Lickey is about 26 miles, that measured east and west from Wolverhampton to Barr Beacon, near Aldridge, is about nine miles.

The tract of ground included within the above-mentioned boundary is for the most part a gently undulating plain, having a mean height of about 400 or 500 feet above the sea. The low level part of the old Birmingham canal, extending from Birmingham to the locks near West Bromwich, is said to be 464 feet above the low-water mark at the docks of Liverpool, the high level part of the canal from the locks to Wolverhampton being 484 feet above the same datum. Numerous branches from this high level part are carried without a lock over the greater part of the central portion of the coal-field, from which near Walsall three or four locks lead up to the still higher branches over the northern part of it, while to the S.W., as we approach Wordesley and Stourbridge, numerous locks take the water down to the level of the river Stour.

There rise from this plain several hills and ridges of higher land, of which the following are the principal:—

1. The ridge of Bromsgrove Lickey, of which the highest point is said to be upwards of 900 feet above the sea.

2. The group of the Clent Hills, of which the highest point is about 950 feet above the sea.

* Dudley is in a detached part of Worcestershire, and Halesowen in a detached part of Shropshire, and little isolated fragments of the three or four counties are, in some places south of Dudley, so intermingled with each other, that it is often impossible to learn from the Ordnance map which county any particular spot may be in.

3. The group of the Rowley Hills, of which the highest is about 820 feet above the sea.

4. The ridge of high ground running from Dudley to Sedgley, of which the most conspicuous points are Dudley Castle Hill, 730 feet; the Wren's Nest, 730 feet; and Sedgley Beacon, 760 feet, above the sea.

5. The high ground about Barr, of which Barr Beacon is the summit, being about 800 feet above the sea.

6. The high swelling plateau of Cannock Chase, the highest point of which, Castle Hill in Beaudesert Old Park, is 900 feet above the sea.*

As the district forms part of the water-shed of England, it can, of course, have no navigable rivers; and its streams are few and unimportant. The high ground that runs from Frankley Beeches to the Clent Hills, gives rise, on the one side, to the little river Stour, running by Halesowen and Stourbridge, to Stourport, where it joins the Severn, and with it flows into the Bristol Channel; while on the other side are the sources of the little river Rea, that flows through Birmingham into the Tame, and thence into the Trent and the German Ocean.

From Frankley Beeches, the water-shed runs through Rowley, Dudley, and Sedgley, to Wolverhampton. On the west of that ridge the streams run either directly into the Stour, or into the Smester Brook, which, rising just west of Wolverhampton, runs nearly due south to join the Stour near Stourbridge. On the east of the ridge, lying between it and the high ground of Barr Beacon, is the basin of the Tame river; the sources of this river are near Bloxwich, whence it runs south and south-east to Aston near Birmingham, and after receiving the Rea, sweeps off northward to Tamworth, in order to join the Trent. In the northern part of the district, the drainage runs entirely into the Trent, the eastern brooks running directly into that river, the western streams flowing first into the Penk, which after joining the Sow near Stafford flows into the Trent at Great Haywood.

The river Trent, coming from the N.N.W. to this spot, bounds the district on the N.E., cutting it off by a very well marked and sudden depression; the mean height of the Trent valley here being not more than 250 feet above the sea.

CHAPTER II.

Description of the Rocks.

The rocks, or geological formations, entering into the structure of this district are—

Secondary, or Mesozoic Formations. { 1. The Lias. 2. The New Red Sandstone.

* These heights are only approximate; but they are believed to be within 20 or 30 feet of the truth.

Primary, or Palæozoic Formations.	3. The Lower Red Sandstone, or Permian. 4. The Coal-Measures. 5. The Silurian Rocks.
Igneous, or Unstratified Rocks.	Basalt and Greenstone.

1. *The Lias.*

Although not strictly lying within the district, I mention this formation because its existence in Staffordshire was first discovered during the survey of the coal-field, and because it may have a rather important bearing on some of the theoretical results arrived at. It occurs on the high ground of Needwood forest. It consists of alternations of blue shale and limestone, the bands of limestone being not more than 6 or 8 inches in thickness, over which are some arenaceous beds becoming in the upper part a white shaly sandstone. The limestone bands have not yet been worked, but they would probably have the same hydraulic character as those of Barrow-upon-Soar.* My colleague Mr. Howell, however, who mapped this neighbourhood, informs me that the limestone here is more argillaceous, and not so pure as the Lias limestone of other places, that near Stratford-on-Avon for instance. In the sandy beds are some imperfect casts of bivalve shells.

CHAPTER III.

DESCRIPTION OF THE ROCKS—*continued.*

2. *The New Red Sandstone.*

SINCE the publication of the first edition of this Memoir, the New red sandstone of the midland counties has been thoroughly surveyed, and its several parts analysed much more completely than before.

This has been done chiefly by the labours of Messrs. E. Hull and H. H. Howell, under the direction of Professor Ramsay, who now supplies the following abstract of the results which have been arrived at, in the passages included within inverted commas.

"The New red sandstone around the South Staffordshire coal-field consists of the following subdivisions:—

		Maximum Thickness. Feet.
Keuper beds.	Red Marl - - - -	600
	White and Brown Sandstone with beds of Red Marl. Waterstones -	300
Bunter beds.	Upper Red and Mottled Sandstone -	500
	Conglomerate or Pebble beds -	500
	Lower Red and Mottled Sandstone -	200

* My attention was directed to this Lias district by my friend Mr. T. Turnor, of Abbotts Bromley, who had himself a suspicion of its true character from the observations of his friend Mr. E. Pickering.

"The division of the Bunter beds into three sub-formations was first made out by Mr. Hull while mapping the New red sandstone near Coalbrook Dale, and I considered it so important that, with the approval of the late Sir Henry De la Beche, I instructed the members of the Survey engaged on the New red sandstone to map all the subdivisions, more especially as in doing so we had a means of detecting a number of the faults that traverse the country.* This accordingly has been done from the south end of the Malvern hills to Lancashire and Nottinghamshire, and the sub-formations have been found always to maintain the same order of superposition, although occasionally one or more members may be absent. In general they are easily distinguishable from each other, except when the Upper and Lower Red and Mottled sandstones chance to be brought together by faults. All of them occur in the district described in this Memoir."

KEUPER.—*The Red Marls.*—This subdivision is principally composed of marl of a dull red colour, with occasional thin bluish shaly beds, containing sometimes small layers of bluish-white sandstone a few inches thick. In the bottom part of the marls occur local beds of sandstone some feet in thickness, sometimes brown, sometimes yellow or white, containing few or no pebbles, generally rather shaly, and not often marked by oblique lamination. The marls are likewise generally shaly, and are sometimes slightly arenaceous, especially in the lower beds. Like all marls, they, when dry, frequently crumble into small cuboidal fragments.

In Staffordshire neither the gypsum nor the salt of this subformation is very abundant. Beds of gypsum may be seen cropping to the surface in several places about Tutbury and Uttoxeter, and the substance is met with elsewhere in wells and pits. The salt is only known by the occurrence of brine springs, which are met with at two places, one at Silkmoor, 1½ mile south of Stafford, the other at Shirley Wych, near Weston-upon-Trent. At the latter place there is a shaft sunk to the depth of 414 feet, of which Mr. Hull procured the following section:—

	FT.
Drift sand and gravel - - -	54
Gypsum - - - - -	6
Red marl - - - - -	354
	414

It is probable, therefore, that the total thickness of this subformation cannot be much less than 600 feet.

Waterstones.—"At the base the Red marl passes into or rather alternates with beds of white and brown sandstone, formerly considered the uppermost part of the Bunter beds, but now placed by the survey as the lowest member of the Keuper series, and called the Lower Keuper sandstone or Waterstones. These strata are the

* This may some day throw much light on the mode of working the coal below, should it ever be searched for and found.

equivalents of the sandstones of the Peckforton hills and of Warwick, which contain Labyrinthodon remains, and in the district surrounding the South Staffordshire Coal-field fossil plants were found in them near Bromsgrove, and a small ganoid homocerque fish, described by Sir Philip Egerton under the name of *Dipteronotus cyphis.*

"Frequently the beds are rippled or current marked, and also traversed by sun cracks, showing that some of them were alternately covered by water and exposed to the air.

"This subdivision occurs in great force round Bromsgrove and in the country between Ombersley and Stourbridge. It lies in the form of a synclinal curve, widening to the south, where it is overlaid by a broad tract of red marl. The sandstone series is here probably from 200 to 300 feet thick. It also occurs on Penn Hill and Oreton Hill as a faulted outlier, and further north it ranges from Whitwick to Penkridge, expanding in places to a width of several miles. Its base partly consists of calcareous breccia and conglomerate, and its greatest thickness is probably about 300 feet.

"On the east of the Coal-field equivalent strata of the same general type (occasionally interrupted by faults) run from the Caradoc sandstone of the Lickey Hills, by Birmingham, to the north of Sutton Coldfield, and from the border of the Coal-field at Cannock Chase to the Trent near Lichfield.

"BUNTER.—*The Upper Red and Mottled Sandstone.*—The Upper Red and Mottled sandstone round the South Staffordshire Coal-field invariably succeeds, in descending order, the strata described above. It varies in thickness from 400 to 500 feet, and generally consists of fine bright red sand, sometimes streaked and mottled with yellow. These sands are often false bedded, but they never contain pebbles. On the east side of the Coal-field this sub-formation ranges from the neighbourhood of Harborne by Birmingham to Sutton Coldfield, and again from the southern part of Cannock Chase eastward to Shenstone. On the west the beds strike in a narrow strip from the Birmingham and Gloucester railway to Hagley, and elsewhere, interruptedly and broken by faults, from the neighbourhood of Stone in Worcestershire to Tettenhall near Wolverhampton. A patch about 5 miles in length also occurs west of Cannock, between Cross Green and Manstey Wood. Good sections may be seen in a cutting of the Birmingham and Gloucester railway, south of Blackwell station, in the new cemetery at Birmingham, in the road cuttings about Tettenhall and Compton near Wolverhampton and at other places marked by arrows on the map.

"*The Conglomerates or Pebble Beds.*—The pebble or conglomerate beds lie below the Upper Red and Mottled sandstone. They vary in thickness from 300 to 500 feet, and in our district are probably thickest south of the Lickey Hills and in Cannock Chase, north of Cannock. They range from a fault near Blackwell station south of the Lickey, to Hagley, lying here directly on the Permian strata, without the intervention of the Lower

Red and Mottled sandstone. West and north of Hagley the same strata, repeated by faults, run from the neighbourhood of Church Hill and Heathside to Wolverhampton and the country west of Trysull, and beyond Wolverhampton they strike northward to Cannock in a band on an average about a mile wide. North of Cannock they widen out, and form almost all Cannock Chase between Rugeley and Bednall. On the east the chief area lies between Harborne, Sutton Park and the Brown Hills, where the New red sandstone is faulted against the Coal-measures.

"The conglomerate is generally more or less incoherent, but occasionally it is cemented into hardish rock by the presence of carbonate of lime. In general, however, it still so completely retains its original character of gravel, that it may be dug out with the pickaxe and shovel, and is used for gravel pits. Occasionally it consists chiefly of sand, with only a few scattered quartz pebbles, as, for instance, in the small patch between Northfield and Frankly.

"The pebbles found in these conglomerates consist chiefly of brown and liver-coloured quartz rock, well water-worn and rounded. These were for long considered to have been derived from the waste of the altered Caradoc sandstone of the Lickey Hills; but when we consider that the same conglomeritic formation, only interrupted by faults, extends all the way from the neighbourhood of Stourport to Lancashire and Nottinghamshire (wherever it has been mapped by the Geological Survey), it is evident that the pebbles have been derived from some other source, the locality of which is unknown. Besides these, there are other occasional pebbles of white quartz, coal-measure sandstone, or millstone grit (stigmaria markings being sometimes discernible in them), chert containing casts of crinoidal stems from the mountain limestone, dull red sandstone, traps, agates more or less decomposed, altered slate, and jasper."

The Drift gravel that more or less covers the country is in a great measure derived from the waste of this conglomerate, and without practice it is at first, sometimes, very difficult to distinguish between these ancient gravels of the New red sandstone period and the other gravels that belong to the much more modern period in which "the Drift" was formed.

In examining a gravel pit for this purpose, the first thing to look for is a chalk flint. True chalk flints, with chalk fossils, may be in some places pretty abundantly found in the gravels of Staffordshire, as sometimes also oolitic and liassic fossils.* Where these occur they are, of course, conclusive evidence against the gravel being of the New red sandstone period. Very often, however, there are large deposits of gravel belonging to the Pleistocene or some of the more recent periods, in which no fragments of rock are found that can be identified with anything newer than the Coal-measures. Still, even these may, after a little practice, be

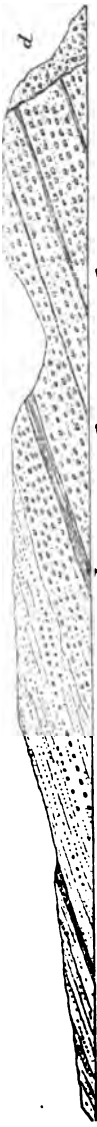
* Gryphæa incurva and large fragments of ammonites and other fossils are sometimes found in great abundance in patches of red clay, belonging to the Drift deposits, near Wolverhampton and other places.

distinguished from the New red (or Triassic) gravels, by their more irregular heaped-up method of deposition; by the sand in which the pebbles lie being of a paler and yellower colour than that of the New red; by the pebbles lying edgeways and confusedly, instead of horizontally and more or less regularly stratified; by the pebbles being often dirty, while those of the New red are generally quite clean (a remark of Mr. Hull's), and by a vague but sufficiently appreciable *facies*, which is not describable, but can be learnt by a little practice, and by that alone.

Figures 1 and 2 represent two modes of occurrence of the conglomerates in the New red sandstone.

Fig 1.

Road cutting near Wordesley, 2 miles north of Stourbridge.

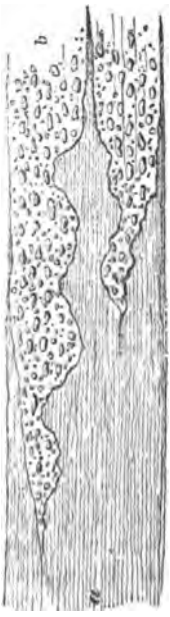


Scale, 1 inch = 40 feet.

a. Brick-red sandstone.
b. Bands of red marl.
c. Conglomerate, gravel of New Red period.
d. Debris, &c., gravel of the Drift period.

Fig 2.

Canal cutting near Brown Hills, Cannock Chase.



Scale, 1 inch = 10 feet.

a. Fine brick-red sandstone. *b*. Conglomerate, gravel of the New Red period.

"*The Lower Soft Red and Mottled Sandstone.*—The Lower soft red and mottled sandstone, when the section is complete, invariably comes between the pebble beds and the Permian or Coal-measure strata of our area. It is in general a bright red soft sandstone, occasionally streaked with yellow and white, and in most points strongly resembles the Upper soft red sandstone. It is, however, generally coarser and exhibits more false bedding. It is quite destitute of pebbles. Between the south end of the Lickey Hill and Hagley it is absent, the Pebble beds resting directly upon the Permian breccias; and the same is the case on the north and east of the Coal-field. West of Stourbridge it underlies the pebble beds in a narrow strip dipping east, and nearly 5 miles long, being faulted on the west against the Upper soft red sandstone. Still further west, repeated by this fault, it runs north from Kinfare by Spittlebrook Mill.

"On the east side of the Coal-field it is entirely absent, the Pebble beds resting directly on the Permian strata. Its thickness is very variable, and probably within the limits of the map described it never exceeds from 100 to 200 feet, but further west, in parts of Shropshire, it is very much thicker."

A. C. R. & J. B. J.

CHAPTER IV.

Description of the Rocks—*continued.*

3. *The Permian Rocks, or Lower Red Sandstone.*

If the survey had been confined to the immediate neighbourhood of the South Staffordshire coal-field it would have been impossible to have obtained sufficient evidence for establishing a boundary between the New red and the Lower red sandstone. In North Staffordshire, however, better sections exist, and my colleague, Mr. Hull, in examining that district, was enabled to acquire a knowledge of the characteristic distinctions of the two formations, which he afterwards brought to bear on the examination of our district. Professor Ramsay having visited North Staffordshire with Mr. Hull, afterwards went over part of the South Staffordshire district with Mr. Hull and myself. The description of this formation, therefore, must be taken as the result of our joint labours.

It is as well to premise that the lithological distinctions between the rocks of this formation and those of the New red sandstone are often rather vague and sometimes but small. This is more especially true with respect to the second or Waterstone subdivision of the New red sandstone, the dark brown or pale red sandstones of which, with their interstratified marls and calcareous bands, are scarcely distinguishable by any lithological characters from similar

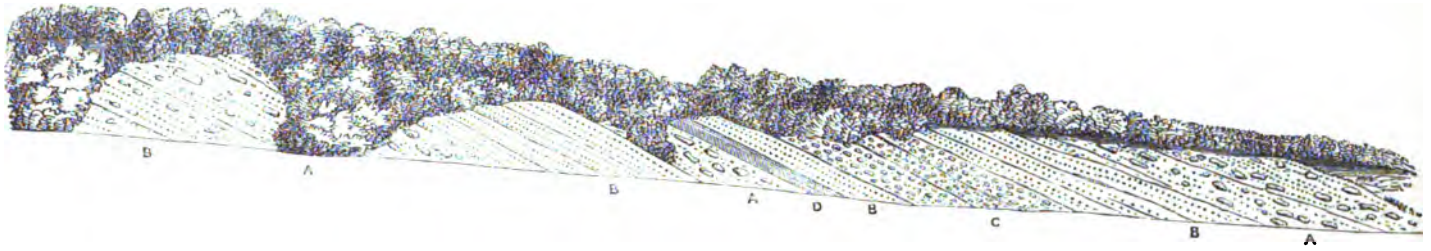
beds in the Permian formation. There are, however, we believe, no brick-red sandstones like that of the Bunter, and scarcely any quartzose conglomerate to be found in the Permian formation; whenever, therefore, we get the above-named doubtful beds in our district, we can determine their geological horizon simply by their place with regard to the soft red and mottled sandstones and quartzose conglomerates. There are two parts of the district from the examination of which it is possible to arrive at a tolerably complete notion of the structure and sequence of the Permian rocks, namely, the country about the Lickey and Clent Hills, and the neighbourhood of West Bromwich.

The country about the Lickey and Clent Hills.—The south end of the Lickey Hill, that on which the obelisk stands, is composed of the quartzose conglomerates and red sandstone, believed to be there the base of the New red. On the northern end of the Lickey, about Square Coppice, as also on all the summits of the high ground of Segban, Romsley, Frankley Beeches, and the higher parts of the Clent Hills, where we get what appear to be the highest of the Permian beds in their respective localities, we find these beds to consist of a remarkable trappean breccia. This breccia is principally made up of angular fragments of trappean rocks, but almost equally angular fragments of many other rocks are found in it. A good section of this trappean breccia is shown in a road cutting just north of the brook in the lane leading from the Bell Inn, at Northfield, to Bangham Pit. The matrix of the breccia is here a brown sandstone, in places calcareous, interstratified with thin bands of marl. The imbedded fragments, some of which are slightly rounded, but the majority remarkably angular, vary in size from mere grains to blocks a foot or a foot and a half in diameter; they consist of porphyritic trap in many varieties (but no basalt or greenstone) of sandstone of various kinds, of quartz-rock, and of Silurian limestone and sandstone, some of which is certainly Llandovery sandstone, not at all altered. There are slabs of these Silurian limestones and sandstones at least 1 foot to 1½ foot square and 5 or 6 inches thick, with their edges scarcely at all rounded. The whole mass has a well-stratified character, and in some places is firmly compacted together by carbonate of lime, but in others is more or less incoherent. The slabs of Llandovery sandstone are now easily split into thinner flags by a very slight blow, and some of them seem to be already so separated in the ground. This, together with their angular character, inclines me to believe that they have not travelled many yards from their original site, and that a boss, or peak, or ridge of the Silurian sandstone lies concealed under the Permian rocks somewhere close by.

The following rough sketch (see Fig. 3), drawn to scale with a measuring tape, will give an idea of the mode of occurrence of these breccias as seen in the bank of the lane above spoken of.

Fig. 3.

Diagrammatic sketch of the Permian sandstone and breccia in the bank of the lane leading from the Bell Inn, Northfield, to Bangham pit. Length of sketch about 80 yards.



A. Coarse sandstone and conglomerate, containing large angular blocks and slabs of shelly sandstone, from 16 to 18 inches long, and 4 to 6 inches thick.

B. Fine sandstone, sometimes containing pebbles and smaller angular fragments.

C. Hard, very regularly stratified breccia of flat angular fragments.

D. Bed of red or brown marl.

In the Clent Hills the breccia has a red marly base, and is chiefly made up of large and small angular fragments of a dull red felstone porphyry, often much decomposed, and splitting, when struck with the hammer, along concealed joints, so as to expose no fresh fracture; of fragments of greenstone; of one or two kinds of sandstone; "with several fragments of a porcelanic-looking slaty rock, like some of those west of the Stiperstones. Near St. Kenelm's chapel this breccia passes down into 1, red marl, with small brecciated fragments at the top; 2, red standstone; 3, red marl; 4, calcareous sandy rock."*

On Romsley Hill, going down into Hunnington, just below the trappean breccia, was found a dull brown sandstone, with a band of calcareous concretionary sandstone. Near a place called Newtown, about a mile to the east of that, are quarries where a similar concretionary calcareous sandstone (a regular cornstone) has even recently been burnt for lime. In going down the brooks from this point to Twylands and Cooks Woods, we get numerous alternations of brown, or brownish grey, or purple, or pale salmon-coloured sandstones, sometimes thick-bedded, sometimes flaggy, with beds of marl, either dark purple with light-coloured spots or blood-red. Many of the sandstones are calcareous and concretionary, and might be mistaken for some of the cornstones of the Old red. A dark purple sandstone, with minute white specks, is a characteristic bed. All these beds are apparently horizontal, being successively exposed only by the rapid fall of the ground; and near the bottom of the slope the blueish grey sandstones and shales of the coal-measures appear from underneath them, likewise in a horizontal position.

The neighbourhood of West Bromwich.—In the cutting of the Birmingham and Dudley railway, south of Sandwell Park, were seen rising to the west, from under a thick mass of quartzose conglomerate, a series of brown and pale sandstones, with merely a few small and slightly angular pebbles. In these beds are masses, believed to be *in situ*, of a singular calcareous conglomerate that is better shown in other places. Under them, we have other pale sandstones alternating with bright red marls, all rising to the westward at an angle of about 10°. We have an account of a boring made hereabouts near "The Ruck of Stones," some years ago, by Mr. J. W. Unett (see Vertical Sections, sheet 18, No. 27), consisting entirely of alternations of red, brown, and grey sandstones of various degrees of hardness, with many beds of red marl, mottled clunch, and other similar materials, all evidently belonging to the formation we are now describing. The depth of the boring was 221 yards 1 foot, or 664 feet.

Nearly a mile west of this, and therefore commencing in much lower beds than are seen in the railway cutting, we have several deep coal pits, the most remarkable of which are those formerly sunk by Messrs. Davis at Bullocks farm, near Spon-lane (see Vertical Sections, sheet 18, No. 28). In these pits they passed

* Professor Ramsay's MS. Notes.

through a mass of sandstones and marls belonging to this formation, 262 yards 2 feet, or 728 feet thick, or, deducting the odd 28 feet for surface drift, &c., 700 feet of Permian, a good part of which at all events, if not the whole, must be below the 660 feet passed through at the "Ruck of Stones." What makes the section of these pits most remarkable, however, is that there occurred in them a small seam of *true Permian coal.* The following is an abstract of the upper part of the section :—

	FT.	IN.
1. Sand, &c. - - - - -	28	6
2. Alternations of red sandstone with red and mottled marls and clays - - - -	169	0
3. Fire-clay - - - - -	3	0
4. White binds - - - - -	12	0
5. Little coal - - - - -	0	10
6. Fire-clay - - - - -	3	8
7. Red clay and sandstone - - - -	28	0
8. Dark and pale red sandstones - - -	213	6
9. Alternations of red and white sandstone, with red and mottled clays and marls - - -	270	0
	727	6

I saw masses of the fire-clays Nos. 3 and 6 on the pit bank while these pits were being sunk, and they did not differ either in colour or in any mineral character from the fire-clays of the coal-measures, except in having small calcareous nodules interspersed through them. These nodules were carefully searched for fossils, but none were discovered. In the red sandstones below, however, numerous rough casts of the large stems of plants, something like rude *sigillariæ* occurred.* Part of the 10-inch coal was shaly and rotten, but about two inches of it is a beautifully bright coal, highly bituminous, very brittle, with curious circular concentric concretionary markings.

At Lord Dartmouth's pits at West Bromwich Heath, there appears to be 268 yards 2 feet, or 806 feet of Permian rocks, alternations of red sandstone and marl, but without any grey fire-clay and coal. At the Lyng colliery there was 550 feet, at the Lewisham pits 315 feet, and at the Terrace pits, close to the fault, they had 135 feet of "red rock" (see Horizontal Sections, sheet 25, No. 7).

It appears, then, that there must be in the neighbourhood of West Bromwich a total thickness of 1,500 feet at the very least, composed of the rocks of this formation.

I have yet to describe the calcareous conglomerate mentioned above. This is well shown at Barnford Hill, two miles south of Oldbury, and thence to Brand Hall. It is composed almost

* These large stems of plants, as also the pale sandstone in which they lay, were exactly similar to those got by Professor Sedgwick from the Lower red sandstone under the Magnesian limestone in the county of Durham, specimens of which are in the Woodwardian Museum at Cambridge.

entirely of rounded and semi-rounded fragments of mountain limestone and chert, with some pebbles of sandstone that may be millstone grit. It is about 20 feet thick, and is in several places quarried and the limestone pebbles burnt for lime. It occurs again in a field opposite the Gough's Arms, at Great Barr, as also in Baggeridge woods on the west side of the coal-field.

Besides this calcareous conglomerate, many of the sandstones sank through in the pits, or exposed in the quarries and cuttings, are very calcareous, like those before described in the district south of the coal-fields.

The reader must be pleased to bear in mind, that these descriptions of the Permian and New red sandstone rocks are meant to apply solely to the district of the South Staffordshire coal-field and its immediate neighbourhood. The Permian rocks of the neighbourhood are believed to be variable, both in lithological character and in thickness, with perhaps many frequently recurring characteristics, but no uniformity. The thickness of the formation is believed to vary almost indefinitely within the limits of 1,000 or 3,000 feet.

Professor Ramsay, in his paper on the Permian breccias in the Geological Journal,* gives a more full and complete account of them than is contained in the above brief observations, and takes a different view as to their origin. He first of all describes those about Enville, where the Permian rocks are largely developed. The breccias there consists of "angular or sub-angular" fragments, "with "flattened sides and but slightly rounded edges," embedded in "a deep red hardened marly paste. The pieces collected consist "chiefly of fragments of micaceous schist, micaceous sandstone, "quartz rock, grey sandstone, chert, purple grit, green sandy slate "(one of them polished and scratched), black slate, altered slate, "greenstone, felstone, felspathic ash, and reddish syenite. The "last is doubtful. A nodule of ironstone was also observed, and "a few quartz pebbles. None of them are larger than 6 or 8 "inches in diameter."

He then describes the breccia of the Clent Hills in the following terms:—

"The breccia here consists of pieces of various rock embedded in a hardened red marly paste. Like those near Enville, they are generally angular, or have their edges but slightly rounded. Their sides are often flattened, sometimes polished, and occasionally scratched. They rarely exceed a foot in diameter. On Clent Hill the fragments consist of felstone porphyry, greenstone porphyry, greenstone amygdaloid, ribboned slate, black and green slate, red sandstone, quartz conglomerate, and felspathic ash. In a section near Romsley stones of the same nature were found, including altered sandstone, conglomeritic ash,

* On the occurrence of angular, sub-angular, polished, and striated fragments and boulders in the Permian breccia of Shropshire, Worcestershire, &c., and on the probable existence of glaciers and icebergs in the Permian epoch, by Andrew C. Ramsay, F.R.S., F.G.S., Geol. Journal, vol. ii. p. 185.

banded felspathic ash, quartz rock, variegated marl, quartz pebbles, altered slate, ribboned slate, and blocks of a coarse conglomerate.

"The igneous rocks of Staffordshire are very different from those in the breccia; and none of the other kinds quoted occur in that district, with the exception, perhaps, of the quartz rock, which might be compared to that of the Lickey."

Professor Ramsay then goes on to show reasons why even the quartz rock fragments are not derived from the Lickey, but as the facts mentioned by him will, in my opinion, admit of a rather different interpretation to that which he gives them, I proceed to his description of the breccia near Northfield.

"The summit of the hill, called Frankley Beeches, is crowned by an outlier of the breccia; and it also forms a piece of ground about a mile and a half long, a little to the north-west of Northfield, a good section* of which occurs in the lane leading from Northfield to Bangham pit. The larger stones lie mostly at the top. Many of them consist of Caradoc limestone (Upper Caradoc† of some geologists), and calcareous sandstone and conglomerate, some of them attaining a diameter of about two feet. I submitted a collection of the fossiliferous pieces to Mr. Salter, who determined the following species:—

"*Strophomena compressa.*
Orthis calligramma.
Atrypa reticularis (very common).
Spirifera trapezoidalis.
Leptæna (*Strophomena*) *depressa.*
L. transversalis.
Rhynchonella semisulcata.
Pentamerus oblongus (rare and small).
P. undatus.
P. lens.
Mytilus mytilimeris.
Encrinurus punctatus.
Favosites alveolaris.
Petraia bina.
P. subduplicata.
Heliolites interstinctus.
Scalites (*Raphistoma*) *lenticularis.*
Euomphalus funatus (var. *sculptus*).
Goniophora cymbæformis.
Serpulites.

"Besides the blocks containing these fossils, the breccia includes fragments of other calcareous sandstone, ribboned slate like that near Shelve, quartz rock, porphyritic felspathic ash, felstone and greenstone like that of the Lower Silurian rocks, purple conglomerates similar to those of the Longmynd, and yellow sandstone and black chert, the latter like that of the Carboniferous limestone.

"The Upper Caradoc (Llandovery) limestone and fragments of calcareous sandstone and conglomerate are peculiar. They do not resemble the Caradoc beds of Walsall, Builth, Malvern, Mayhill, or the Lickey; but both lithologically and zoologically they are like the equivalent strata that rest unconformably on and once formed the

* This is the section drawn in Figure No. 3.
† Now called Llandovery sandstone.

beaches surrounding the Longmynd and adjacent Lower Silurian rocks, where *in situ* they contain green and purple slaty fragments and pieces of felspathic trap, derived from the waste of that ancient Cambrian and Lower Silurian island. They may be identified by this circumstance, for in no other place with which we are acquainted does the Upper Caradoc assume this character; and Mr. Salter also gives the confirmatory opinion that the assemblage of fossils nearly resembles some of the groupings in the present rocks near Hope. It is, therefore, difficult to escape from the conclusion that the rocks generally must have travelled from that country across a space of from forty to fifty miles."

As I had no personal acquaintance with the Llandovery rocks on the flanks of the Longmynd, near Church Stretton, I failed to recognize the fragments of slate and other rocks which were found by my friend and colleague in the pieces near Northfield until I saw his collection in Jermyn Street, and many of the pieces certainly appeared to me, as before stated, very like the sandstones near Barr, and the pieces which were formerly to be seen lying on the old pit banks north of the Colmers near the Lickey.

Professor Ramsay then describes other localities where this Permian breccia appears, between the Forest of Wyre and the south end of the Malvern Hills. One of these localities, called Church Hill, nearly half way between Stourport and the Titterstone Clee Hill, is very remarkable, since it forms an outlier of the breccia resting upon and entirely surrounded by Coal-measures. Professor Ramsay shows that these breccias extend altogether over an area of not less than 500 square miles,* and points to the fact that the great majority of the angular fragments seem to be all derived from the neighbourhood of the Longmynd near Church Stretton.

He arrives at the conclusion, from this great extension of the breccia, from the size (up to three-quarters of a ton) and angularity of the embedded fragments, and from the polished and grooved and striated surfaces of some of them, that they were transported and deposited by the same agency as the boulders in the boulder clay of the Pleistocene or Glacial Period, namely, by the action of glaciers, and icebergs or shore ice and ice floes.

As the action of glaciers is a subject to which my colleague has paid so much more attention than I have, his opinion is entitled to much more weight on the point than any I could give, and I therefore would draw the reader's attention to Professor Ramsay's explanation of the origin of this breccia, in opposition to the conclusion that I myself arrived at, that the fragments might be derived from adjacent rocks now concealed under the Permian and New red sandstone of the neighbourhood.

* See also his lecture to the Royal Institution, April 24, 1857.

CHAPTER V.

Description of the Rocks—*continued.*

4. *The Coal-Measures.*

General Description.

The Coal-measures of North Staffordshire consist very largely of argillaceous (or clayey) materials, more or less mingled or alternated with arenaceous (or sandy) and carbonaceous (or coaly) substances. These different beds have various local names, of which the following is a nearly complete list:—

Argillaceous Materials.—Clunch,—a tough clay, breaking into blocks; sometimes rather sandy, generally grey or yellowish.

Binds,—shaly clay, close, smooth, compact, and splitting into regular laminæ, generally blue, or some shade of grey.

Clod, ground, earth,—earthy clay, generally of a blue or black colour.

Batt or bass,—highly carbonaceous* shale, commonly very compact, and splitting into the finest laminæ, almost invariably black, and often interstratified in layers with the coal.

Fire-clay,—clay having a certain definite proportion of silica and alumina in its composition with but little admixture of metallic or earthy fluxes, so that on the application of heat it forms a nearly pure silicate of alumina, and therefore makes good fire-bricks. It is generally unctuous to the touch as soon as it is got, which the other argillaceous beds rarely are. It is commonly a brownish grey, sometimes nearly black, but sometimes quite pale.

Arenaceous Materials.—The siliceous or arenaceous beds of the coal-measures have the following local names:—

Rock.†—All sandstones having any degree of hardness or toughness go under this name with the colliers.

Pebbley or bibbley rock,—sandstone with pebbles, conglomerate.

Rotch, or roach, is applied to sandstone when it is softer or more brittle than rock, so as to break easily into small fragments.

Peldon,—a very hard, smooth, compact, flinty stone, with conchoidal fracture.

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* It has been usual hitherto to call this "bituminous" shale, an incorrect term, inasmuch as, though it contains the components of bitumen, it does not contain that substance itself; one might almost as well in speaking of a sack of malt call it a barrel of ale.

† Under the term "rock" the miners likewise include all kinds of trap which occur in the district, using generally the distinctive terms "green rock" and "white rock," according to the colour. The only practical ambiguity that arises from this confusion of terms is in the case of the "white rock;" as, when that term is used, it is sometimes doubtful whether white sandstone or white trap is meant.

Some of these terms are used in composition to describe beds partaking of both characters, as—

Rock-binds,—sandy shale or shaly sandstone.
Clunch-rock,—hard sandy clay, &c. &c. &c.

Carbonaceous Materials.—There is every gradation from a mere carbonaceous shale or batt through a "slummy," smutty, or batty coal to a perfectly pure bright coal with but very slight admixture of earthy matter.

The coals are usually bituminous, that is, they still retain mingled with the carbon such a proportion of hydrogen and oxygen as would allow of bitumen being formed from them by distillation. Some of them, indeed, are cannel coal, which blazes almost like a candle, and consumes away so as to leave only a little light, white, powdery ash.

Usually, however, the coals are of the variety known as Cherry coal, (see Ronald's and Richardson's "Chemical Technology," vol. i. p. 45,) being got in large blocks, not caking, easily lighted, and burning with a clear, cheerful flame, leaving a white ash, and no very large proportion of cinders.

Ironstones.—The ironstones are all clay ironstone, occurring either in thin regular seams or in layers of nodules, balls, or concretions. The principal kinds have now been analyzed in great detail under the direction of Dr. Percy. (*See* "The Iron Ores of Great Britain," Part II.)

Usually in all local descriptions of the Coal-measures of South Stafford, whenever the word "stone" is used, ironstone must be understood.

Parting and pricking mean the thin layers between the more important beds; they are generally some variety of clay.

Grouping of the Measures.—The way in which the various beds of clay, shale, sandstone, coal, and ironstone are interstratified with each other, may be seen by reference to the four published sheets of Vertical Sections, Nos. 16, 17, 18, and 26. The Coal-measures of South Staffordshire, as of most other districts, are made up of a great series of alternating beds of these materials,—all of them varying in thickness and extent. As a general rule, the beds of coal are more constant in thickness, and extend over wider areas, than the beds of other materials. Next in constancy and persistency to the coals come the finest grained rocks, such as the batts, and the finer varieties of fire-clay and clunch. The sandstones and coarser grained rocks are most capricious in their occurrence, and vary most suddenly in thickness and character.

Beds of coal are not only constant in thickness over very considerable areas, but also generally in quality and character. This is so much the case, that colliers and other persons who have been long engaged in handling the coals of a district will recognize detached blocks of different coals lying loose on the pit bank, even when taken to a distance of some miles from their own pits. They will name the seam each block came from, when to

a less practised eye there seems no appreciable difference between them.

Changes, however, do occur both in the grouping and the quality of beds of coal. Changes in the grouping may occur either in the thickening or thinning of the measures between the coals, separating coals that were together, or bringing together those that were separate, or sometimes, but less frequently, even in the thickness of the coal-seams themselves, the very same bed becoming thicker in one place than another, or thinning out so as to occasionally disappear altogether. When, indeed, it becomes possible to trace a bed of coal over an indefinitely wide area, we must necessarily reach its termination by gradual thinning out in some direction or other.

Changes also occur in the quality and character of coals, so that sometimes, the very same bed or part of a bed, may within a comparatively short space become so altered in quality as to form quite a different variety of coal, and, of course, be no longer recognizable as the same, unless it be actually traceable by continuous working from one locality to the other, or can be referred to continuously traceable beds above or below it.

The South Staffordshire coal-field is distinguished from all others in the British Islands, and from most of those in the rest of the world, by the fact, that over a considerable part of its area a number of coals come together, resting one upon the other, with little or no interstratified shale or "parting" till they form a great seam of coal 30 feet in thickness. This has long been celebrated under the name of the *Thick* or *Ten-yard Coal.* The number of beds composing this remarkable compound seam are reckoned at from 10 to 14 in different places, according to the presence or absence of some of the beds, or of the separations between them. The "partings" of shale between the beds vary also occasionally in number and thickness, so that in some places the aggregate thickness of the coals is not more than 20 feet, with 10 feet of interstratified shales, &c.; while in others, the coals alone attain the dimensions of 36 feet, and with 3 feet of partings, make a total thickness of 39 feet.

The Thick coal retains this structure, more or less completely, over all the district around Dudley as far as Bilston, Wednesbury, Oldbury, Halesowen, Brierly Hill, and Kingswinford. In two of these directions, however, namely, westwards towards Kingswinford, and northwards, towards Bilston, the remarkable phenomenon known as the "Flying reed" seems to point out the commencement of a great alteration in the grouping of its beds. The two upper beds of the Thick coal are separated from the rest gradually, but rapidly, by interposed shales and sandstones, so that in the space of a mile or thereabouts they form a distinct seam, called the "Flying reed," which, towards the west, becomes as much as 100 feet above the Thick coal, and more than 200, towards the north.

Towards the north, also, between Bilston and Wolverhampton, a separation occurs in the middle of the Thick coal, a bed of shale

(sometimes called Hob and Jack), seven to ten feet thick, making its appearance between the "Foot coal" and the "Slips coal." These facts prepare us for the statement, of the truth of which good proof can now be given, that the change in the grouping of the beds was originally much more complete, even within the limits of the coal-field, and that the beds of coal which, coming together in the southern part of the field, form the Thick coal, are the very same beds, or some of them, which are worked now at Essington and Wyrley, and are there all more or less separated from each other by interposed shales and sandstones, so as to make a total thickness of over 300 feet. This change, from a thickness of thirty feet of coal only, to one in which thirty feet of coal are distributed among 300 feet of shales and sandstones, can be shown to have taken place within a horizontal distance not exceeding five miles. It is a kind of change quite familiar to those who are accustomed to trace any set of beds continuously along their strike, though it is not often that it can be so clearly proved and followed out in detail as in the present instance. Two of the coals below the Thick coal also undergo a similar separation towards the north.

Neither is this change in the grouping of the coals the only important change which occurs in the constitution of the field, for some of the lower beds of coal and ironstone which, in the part of the district between Wolverhampton and Walsall, are the richest and most important measures, dwindle away southwards towards Dudley, and farther south than that town have never been found at all in any workable form, though the measures of shale and sandstone in which they ought to lie have been pierced in search of them at several places.

These great changes in the constitution of the Coal-measures make it impossible to give any general section which shall be applicable in all its parts to any one locality. In the former edition of this Memoir this difficulty was evaded by giving, first, a list of the beds above the Thick coal, taken chiefly from the southern part of the field, and then a list of those below it, taken chiefly from the central and northern part. This plan, however, obscured the general view of the whole. It will, therefore, be better to give, first, a general section, compiled from the information to be obtained in the whole of the southern part of the coal-field from Bentley to Halesowen (Map 62, S.W.), and then another general and comparative section, applicable to the northern part of the district, from Bentley as far as Wyrley on the one side, and the Brown Hills on the other (Map 62, N.W.)

The first general section will include the mention of every workable bed of coal and ironstone in its proper place in the series, without regard to the locality in which it occurs. The second, while it agrees pretty nearly with the first in the lower measures (since each includes the Bentley district), will exhibit in the upper part the change before alluded to as occurring in the grouping of the coals forming the Thick coal, as well as some other changes in the lower beds.

As a more easily remembered key to the structure of the district than that of the general section it may be as well to give the following abstract list of the principal workable coals in the southern district in descending order:—

	FT.
Upper measures, maximum thickness - - about	800
1. Brooch coal - - - - - - about	4
Intermediate measures varying in 25 pit sections from 87 to 218 feet - - - - - - mean	130
2. Thick coal - - - - - - about	30
Intermediate measures varying in 33 pit sections from 7 to 35 feet - - - - - the mean being	20
3. Heathen coal - - - - - - about	4
Intermediate measures varying in 33 pit sections from 56 to 144 feet - - - - - the mean being	109
4. New Mine coal - - - - - about	8
Intermediate measures varying in 43 pit sections from 2 feet to 35 feet - - - - - the mean being	16
5. Fire-clay coal - - - - - about	7
Intermediate measures varying in 40 pit sections from 18 to 52 feet - - - - - the mean being	30
6. Bottom coal - - - - - - about	12
Lower measures - - maximum proved thickness	140
	1,310

This total of 1,300 feet is probably greater than the thickness of Coal-measures that ever existed at any one place in the southern half of the South Staffordshire coal-field.

GENERAL SECTION of the Central and Southern Part of the Coal Field.

		FT.	FT.
1.	* Beds above the Upper Sulphur coal - - - - { 1*a*. The Halesowen sandstone group; 1*b*. The Red coal-measure clays }	600 to 800	
2.	† Upper Sulphur coal - - -	about	1
3.	Intermediate measures - - - -	„	140
4.	† Little or Two-foot coal - - - -	-	2
5.	Intermediate measures - - - -	from	2 to 48
6.	(I.) BROOCH COAL - - - -	about	4
7.	(*I. 1.*) Brooch binds, ironstone measures -	from	7 to 20
8.	† Herring coal ‡ (not known north of Dudley) - - - -	about	1
9.	(*I. 2.*) Pins and Pennyearth ironstone measures § - - - -	from	7 to 30
10.	Intermediate measures containing the sandstone known as the Thick coal rock -	„	38 to 157

* Each group of beds is numbered in consecutive order, the workable coals having an additional number in Roman figures, and the ironstones an additional number with *I.* before it.

† The coals thus marked are not numbered, as they have never yet been worked.

‡ So called from containing many dorsal spines of fish, called herring bones by the colliers.

§ These ironstones are occasionally rich in the remains of fishes.

			FT.	FT.
11.	(*I. 3.*) Broad earth, Catch earth, and Batt, containing the Ten-foot, and Backstone ironstones in the Pensnett district -	from	6 to	14
12. THICK COAL.	(II.) Roofs coal or top floor - -			
	(III.) Top slipper, or Spires, or Spin coal - These two form the Flying reed when separated from the coals below.			
	(IV.) Jays, or White coal - - -			
	(V.) Lambs, or Floors, or Fine Floors coal These two are often either mentioned together under the name of White coal, or else the lower one is absent.			
	(VI.) Tow (tough) or Heath coal - -			
	(VII.) Benches coal (this bed is but rarely mentioned).		about	30
	(VIII.) Brassils or Corns coal - -			
	(IX.) Foot coal, or Bottom Slipper, or Fine coal.			
	(X.) John coal, or Slips or Veins coal -			
	(XI.) Stone, or Long coal - -			
	(XII.) Patchells coal (sometimes absent or not [illegible]).			
	(XIII.) Sawyer or Sl[illegible]s coal - -			
	(XIV.) Slipper coal - - -			
	(XV.) Bottom Benches, or Omfray (Humphrey), or Red, or Kid (Kick?), or Holers coal.*			
13.	(*I. 4.*) Pouncill batt, Blacteryand Whitery, containing the Grains ironstone, and sometimes the Whitery iron stone.† -	from	2 to	8
14.	(*I. 5.*) Gubbin ironstone measures, sometimes called the Little, or Top, or Thick coal gubbin, sometimes the Black ironstone - - - - -	„	2 to	8
15.	Table batt and intermediate measures - -	„	2 to	28
16.	(XVI.) HEATHEN COAL - - -		about	3
17.	Intermediate measures (sometimes wanting) -	from	0 to	43
18.	(XVII.) RUBBLE, or LOWER HEATHEN coal, sometimes, when the measures above are wanting, forming the bottom part of the Heathen coal, sometimes itself wanting, when the measures above and below seem to be both present - - - -	„	2 to	4

* Beds numbered as XV., XIV., XIII., XI., X., IX., VIII., VI., with either IV., or IV. and V. grouped as the White coal, are always present wherever the Thick coal is at all in the normal condition; where III. and II. have gone off as the Flying reed, the White coal is always the top measure; the beds numbered VII. and XII. are often omitted, either being absent or being grouped with the one above or below them.

† About Bentley there is an ironstone in these measures which is there called the Bind ironstone, and it has a coal called the Bind coal associated with it, which is sometimes 14 inches thick.

		FT.	FT.
19. (*I. 6.*) Intermediate measures containing, at Bentley, the ironstones known as the Lambstone and Brownstone	from	10 to	33
20. (*I. 7.*) New Mine or White ironstone	„	2 to	10
21. (*I. 8.*) Measures containing the Penny-stone ironstone, called also Bluestone or Cakes	„	10 to	25
22. (XIX.) SULPHUR coal	„	2 to	9
23. Intermediate measures	„	3 to	99
24. (XX.) NEW MINE coal *	„	2 to	11
25. (*I. 9.*) Measures containing the Fireclay Balls ironstone occasionally	„	2 to	40
26. (XXI.) FIRECLAY coal (and partings)	„	1 to	14
27. Intermediate measures	„	2 to	10
28. (*I. 10.*) Getting Rock ironstone (occasional)	„	4 to	5
29. (*I. 11.*) Poor Robin ironstone measures	„	3 to	5
30. Intermediate measures, sometimes wanting	„	0 to	9
31. (*I. 12.*) Rough hills White ironstone (occasionally)	„	2 to	19
32. (XXII.) BOTTOM coal	„	3 to	12
33. Intermediate measures	„	5 to	30
34. (*I. 13.*) Gubbin and Balls ironstone, sometimes called the Great or Bottom Gubbin	„	3 to	10
35. Intermediate measures	„	18 to	50
36. (XXIII.) SINGING or MEALY GREY coal (occasional)	„	2 to	4
37. Intermediate measures	„	16 to	50
38. (*I. 14.*) Blue Flats ironstone	„	2 to	9
39. Intermediate measures	„	10 to	14
40. (*I. 15.*) Silver Threads ironstone	„	4 to	7
41. Intermediate measures	„	6 to	15
42. (*I. 16.*) Diamonds ironstone	„	2 to	3
43. Lowest measures, maximum thickness known below the Diamonds ironstone		about	50

The variations in thickness, noted in the preceding general section do not take place indiscriminately, but chiefly according to a general rule, the least thickness being almost invariably found to the south, while the greater thicknesses come in regularly as we proceed northwards. There are, however, local exceptions to this statement, in the fact of a sudden thickening or thinning of any particular group of beds in a partial manner, and over a small area, with an immediate return to the normal thickness of the neighbourhood. The group of sandstones known as the Thick-coal rock, and some other sandstones, have these partial thickenings, while the shales between the New Mine and Fire-clay coals, sometimes, as in the Stowheath field, diminish quite unexpectedly to two feet, and then suddenly regain their usual dimensions of 30 or 40 feet. Sometimes, indeed, these two coals are so split up by partings, that when the thickness between

* The New Mine coal is completely separated into two coals at Bentley, there called the Three-foot and the Five-foot, with 33 feet of shale and sandstone, containing ironstone between them.

them is small, it is not easy to determine which is the bottom part of the New Mine and which the upper part of the Fireclay.

Besides this original irregularity in the constitution of the coal-measure series, the present "lie and position" of the beds is such that the uppermost beds of all, the Halesowen sandstones namely, which come in far above the Upper Sulphur coal, are only now to be found around the southern margin of the field, where the beds dip to the south, while all the upper measures and the Thick coal itself have been removed by denudation from the district between Bilston and Bentley, where the lower beds gradually rise to the surface as we proceed towards the north. Neither do the Halesowen sandstones ever appear again further north although the great Bentley fault throws down the beds in that direction, so as to bring in the Thick coals and some of the beds above them, and although as we range to the north, the dip of the measures seems to be first west and then north-west.

We will now proceed to examine the general section of this northern part of the district, that namely, which lies north of the great Bentley fault, as far north as Cannock Chase. In order to make this general section at the same time a comparative one, and point out the locality whence each piece of information is derived, the following distinctive letters will be used; E. for the Essington district, W. for Wyrley, B for Bentley, and P. for Pelsall and the Brown Hills, while the average thickness will be that of all the places where the beds have been mentioned in the pit sections obtained.

GENERAL SECTION of the Coal-measures extending from Bentley to Essington and Wyrley on the West, and Pelsall and the Brown Hills on the East.

		Average thickness. FT.	IN.
1.	Various measures; 20 ft. E.	20	0
2.	(I.) Coal; 2 ft. E.	2	0
3.	Intermediate measures; 37 ft. E.	37	0
4.	(II.) Coal; 1 ft. 9 in. E.	1	9
5.	Intermediate measures, 10 ft. E.	10	0
6.	(III.) Coal, 5 small coals with partings, 12 ft. 6 in. E.	12	6
7.	Intermediate measures, 3 ft. E.	3	0
8.	(IV.) Coal, 1 ft. E.	1	0
9.	Intermediate measures, 66 ft. E.	66	0
10.	(V.) Coal, 2 ft. E.; 1 ft. 9 in. W.	1	10
11.	Intermediate measures, 32 ft. E.; 10 ft. W.	21	0
12.	(VI.) Coal, 7 ft. 6 in. E.; (coals and partings 9 ft. 10 in.) W.	8	8
13.	Intermediate, with a small coal, 57 ft. E.; 76 ft. W.	67	0
14.	(VII.) Old Robins coal, 5 ft. 6 in. E.; 6 ft. 6 in. W.	6	0
15.	Intermediate, 35 ft. E.; 18 ft. to 22 ft. W.	25	0
16.	(VIII.) Wyrley Yard coal, with parting, 5 ft. E.; 3 ft. to 5 ft. 6 in. W.	4	0
17.	Intermediate, including the Yard coal ironstone, 40 ft. E.; 36 ft. to 69 ft. W.	47	0
18.	(IX.) Charles coal, 2 ft. 3 in. E.; 2 ft. 4 in. to 3 ft. W.	2	6
19.	Intermediate, 30 ft. E.; 24 ft. to 64 ft. W.	52	0

		Average thickness. FT.	IN.
20.	(X.) Cannel coal, 3 ft. 8 in. E.; 4 ft. W. - -	3	11
21.	Intermediate, 60 ft. E.; 54 ft. to 84 ft. W. - -	71	0
22.	(XI.) Wyrley Brooch coal, 2ft. E.; 3 ft. 8 in. to 4 ft. W. - - - - - -	3	4
23.	Intermediate, 3 ft. 6 in. E.; 1 ft. to 1 ft. 6 in. W. -	1	8
24.	(XII.) Benches coal, 7 in. E.; 2 ft. to 2 ft. 4 in. W. -	2	0
25.	Intermediate, with a 2 ft. coal, 74 E.; 40 to 48 ft. W. -	54	0
26.	(XIII.) *Wyrley Bottom or Eight-foot, Bentley Old Man's coal; 8 ft. 6 in. with partings E.; 6 ft. to 8 ft. W.; 9 ft. 10 in. B. - -	8	1
27.	Intermediate, 38 ft. E.; 39 ft. to 46 ft. W.; 45 ft. to 61 ft. B. - - - -	46	0
28.	(XIV.) †Essington Four-foot, or Bentley Hay coal, 4 ft. E.; 3 ft. W.; 5 ft. sometimes expanded by shale to 11 ft. B. - -	4	0
29.	Intermediate, 51 ft. to 63 ft. B. - - -	54	0
30.	(XV.) Heathen coal, 1 ft. 8 in. to 3 ft. B.; 2 ft. 6 in. P.	2	0
31.	Intermediate, 44 ft. to 56 ft. B.; 61 ft. P. - -	50	0
32.	(XVI.) Sulphur coal, 1 ft. 6 in. to 4 ft. B. - -	1	9
33.	Intermediate, 21 ft. to 52 ft. B.; 32 ft. to 52 ft. P. -	43	0
34.	(XVII.) Yard coal of Pelsall, 3 ft. to 3 ft. 6 in. B.; 2 ft. 9 in. to 3 ft. 8 in. P. - -	3	2
35.	Intermediate, 31 ft. to 46 ft. B.; 26 ft. to 50 ft. P. -	40	0
36.	(XVIII.) Bass coal of Pelsall, 4 ft. to 6 ft. B.; 3 ft. to 6 ft. P. - - - -	5	10
37.	Intermediate, 21 ft. to 35 ft. B.; 29 ft. to 39 ft. P. -	31	0
38.	(XIX.) Fireclay or Cinder coal, 3 ft. 10 in. to 6 ft. 8 in. B.; 3 ft. 2 in. to 5 ft. P. - -	4	6
39.	Intermediate, 21 ft. to 46 ft. B.; 21 ft. to 49 ft. P. -	33	0
40.	(XX.) Upper part of Bottom coal, or Shallow coal, 2 ft. to 7 ft. 9 in. B.; 4 ft. to 7 ft. P. -	5	4
41.	Intermediate, 8 in. to 8 ft. B.;‡ 38 ft. to 51 ft. P. (average of latter) - - -	46	0
42.	(XXI.) Lower part of Bottom, or Deep coal, 2 ft. 9 in. to 4 ft. 8 in. B.; 5 ft. to 15 ft. P.§ -	6	8
43.	Measures between the Bottom coal and the Silurian shale, 137 ft. B. - - -	137	0
		1,053	0

* This, which is the lowest coal hitherto worked at Wyrley, is the uppermost coal of all in the Bentley district, only coming into the ground, here and there, when the lower beds dip deep enough to allow it to do so.

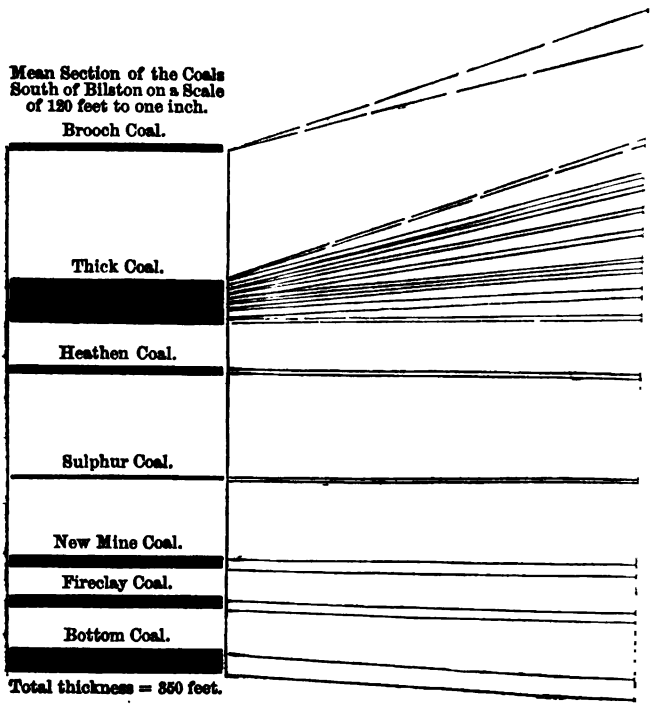
† This coal has been sunk into at Essington, and has also been twice reached, once by boring, and another time by sinking, near Wyrley, where it was found to be only 3 feet thick. The finding of this coal there at the proper distance below the so-called Bottom coal of Wyrley lends a strong support to the identification of that coal with the Old Man's coal of Bentley.

‡ In the Bentley district the Bottom coal is still looked upon and worked as one seam, even when the central parting is several feet thick. It is only N.E. of Goscott that the two parts become so widely separated that they are worked as two beds under the names of the Shallow and the Deep coal. Between Bentley and Goscott the Bottom coal is in one place even called the Thick coal, being the thickest bed known thereabouts.

§ Where the Deep coal thickens to 12 or 15 feet it is in consequence of a considerable parting separating the bottom part of it from the rest. It is probable that further north this separation will become so considerable that the coals will be separately gotten and receive separate names.

(*To face page* 25.)

FIG. 1.—Diagram to show the relation bet
north-central part of the South Staffordshire
from many pit Sections scattered over an are
mean or average thickness of those pits.
distance between the two areas is about five
ought to be placed about 18 feet from each o
shown in Figure 2.


Mean Section of the Coals South of Bilston on a Scale of 120 feet to one inch.
Brooch Coal.
Thick Coal.
Heathen Coal.
Sulphur Coal.
New Mine Coal.
Fireclay Coal.
Bottom Coal.
Total thickness = 350 feet.

If we compared the two general sections now given, on the supposition that the Thick coal of the first was but one coal, we should have only 7 or 8 workable coals in that section to contrast with 21 in the other. By taking into account that the Thick coal is made up in reality of 12 to 14 separate coals, we at once get the fact that the number of coals are in reality nearly the same in both sections. The difference in the two series is then seen to be the result of variations in the other materials, namely, the shales and sandstones with which the coals are interstratified.

It may very well be doubted whether any single bed of coal is ever more than two or three feet in thickness, and we may therefore take it for granted, that every bed which exceeds that thickness over any considerable space is in reality a compound seam made up of two or more beds resting on each other, with or without "partings" of shale, &c. between them. Not only then are many of the beds which are spoken of under one name in the southern part of the district compound seams, but several of those in the northern district also. We may look upon the seams numbered III., VI., VII., VIII., XIII., and XXI. in the second general section as undoubtedly compound seams, liable at any place to be separated into two by interposed shale and sandstone. Some of the others may also be compound seams.

In comparing the two general sections we must recollect that the second does not include any of the 600 or 800 feet of upper measures which form the top of the first, and we shall then see that the bulk of the coal-bearing beds in the second is much greater than the bulk of the coal-bearing beds in the first. Since, however, the quantity of coal disseminated through that bulk is nearly the same in both, or at least is but slightly preponderate in the second, it follows that the increase is in the shales and sandstones interstratified with the coals. Since, moreover, the lower beds are the same in both sections, it follows that the beds above them, those about the Thick coal, are on the same geological horizon, and that the Thick coal of the first is split up somehow into the separated beds of coal to be found in the second.

In Plate I. Figure 1 will be found a representation of this splitting up of the Thick coal and other coals towards the north in a diagrammatic form. The constitution of the beds south of Bilston (which we may call the south central portion of the coal-field) is shown on the one hand in a vertical section on a scale of 120 feet to an inch, and that of the beds at Bentley and north of it, on the other hand, in a similar vertical section on the same scale, each section being a mean or average section deduced from a considerable number of actual pit sections.

The coals known as the Heathen and Sulphur are common to the two sections, the Heathen being assumed as the horizontal datum line.

The Fire-clay and Bottom coals are also common to the two sections being worked continuously from Bilston to Bentley, and thence to Pelsall.

Just at the south end of Pelsall Heath, the Bottom coal, which up to that point has been worked continuously as a single twelve-foot coal, begins to separate into two coals, which about a mile or so farther north are as much as 15 yards (45 feet) apart. These two coals were formerly gotten along their outcrop at the Brown Hills, under the name of the Shallow and the Deep coal. The Deep coal itself is also, a little farther north, beginning to separate into two coals.

The Fire-clay coal has been worked continuously from Bilston up to Bentley, and thence by Goscott to Pelsall, but on reaching the latter place it apparently begins to change its quality and character, and further north is known only as the Cinder coal.

The New Mine coal crops out a little before it reaches so far north as the Great Bentley fault, and when thrown in by that fault, it is found to be separated into two, called at Bentley the Three-foot and Five-foot, but known farther north as the Yard and the Bass coal. That these two coals are in reality the two separated parts of the New Mine coal is shown by the fact that at Bentley they have the Sulphur and Heathen coals next above them, and the Fire-clay coal next below them.

With this tendency to split up into separate coals as we proceed towards the north, clearly proved to exist in the lower beds which run continuously in the ground, we can the more readily allow the probability of a similar tendency in the upper beds, which now only occur in localities more widely separated from each other in consequence of the removal of large portions of the measures by the denudation that has acted over the intermediate space.

In consequence of the denudation having removed so much of the upper measures it is difficult, perhaps impossible, to identify the beds of those upper parts of the two districts with the same precision that we can the beds in the lower measures. It is, however, very remarkable that if we add together the average thickness of the coals in the Wyrley and Essington district, commencing with the Old Robins coal, and including the Essington four-foot or Bentley Hay coal, which there lies next above the Heathen coal, we shall, if we omit the partings, get a thickness of a little over thirty feet (about thirty-three feet), which agrees quite as closely with that of the Thick coal as we could expect.

Whether the Brooch coal of the district south of Bilston, be represented by the Essington sixth coal, or whether the fifth and sixth coals of that locality be new coals, and the third and fourth represent the Brooch, is perhaps a moot point.

If the Old Robins coal be really the top of the Thick coal, or the same as the Flying reed coal, then the Essington sixth coal is at rather a less height above it than the Brooch is above the Thick coal in the southern part of the field. Bearing in mind, however, the tendency to thicken and increase towards the north which the measures below exhibit, we should expect the height to be greater, and should be more inclined, perhaps, to look upon the fifth and sixth coals of Essington, either as themselves the representatives of the Flying-reed, or upper part of the Thick coal, (which will

then not merely be separated by shales, but have a greater thickness of coal than it generally has farther south,) or else consider them as new coals not represented at all in the southern part of the field.

Whatever may be the truth with regard to those points of detail, the general fact of the beds at Essington, Wyrley, and Bentley, from the Old Robins coal down to Bentley Hay coal inclusive, being the representatives of the Thick coal can no longer be doubtful.

It appears that the materials which formed the shales and sandstone, &c. were deposited abundantly and frequently towards the north, but that some of them gradually became less and less towards the south, so that in many cases they finally came altogether to an end in the latter direction, while the coals were deposited equally, or nearly so, over both areas.

The fact now established is one of considerable interest, both as regards the practical working of this and other coal-fields, and as bearing on the theoretical explanation of the origin and formation of coal.

Note on the Fossils, by J. W. Salter, Esq.

The fossils of the ironstones as a whole very much resemble those of the Coalbrooke Dale coal-field. There is the same intermixture of marine shells, shark-like fish, and a few land plants, with a considerable number of unio-like shells (*Anthracosia*), too imperfect for determination in most cases. One species, however, is the *A. bipennis*, Brown, found, both here and in Flintshire, in the coal itself. The marine shells are quite the same as those of the "Pennystone" of Coalbrooke Dale, but they are fewer in number.

The following may be considered characteristic of the ironstones :— *Discina* (*Orbicula*) *nitida* of Phillips ; *Producta scabricula*, Sowerby ; a *Lingula*, which appears to be the *L. elliptica* of Phillips ; *Conularia quadrisulcata*, and the two species of *Myalina* figured by Prestwich, viz., *M. quadrata* and *M. carinata*. The *Aviculopecten scalaris*, Sowerby, is rare. With these are abundance of the large fish defences, called *Gyracanthus formosus*, Agass. ; scales of a large *Holoptychius ;* the *Megalicthys Hibberti ;* and *Cochliodus*. (*Pœcilodus angustus* occurs in bastard coal at the Fens colliery.) There are also traces of *Annelides*, and the usual plants, *Lepidodendron*, *Calamites*, &c., occur.

The localities from which these fossils have been obtained are ;—the pit banks three-quarters of a mile N.E. of Portway Hall near Oldbury, and the Factory north of that place. The *Producta* and *Conularia* are abundant at the former, and the large *Mytilus*-like bivalves (*Myalina*), with the *Lingula* and *Fish*, at the latter.

South and south-west of Dudley, at Queen's Cross, *Holoptychius* and *Myalina* occur in the Gubbin ironstone ; and at the Buffery ironworks the large *Gyracanthus formosus*. The Fens south-west of Dudley have a few shells in the carbonaceous bands, and also a fish-palate, *Pœcilodus angustus*, a species equally characteristic of similar beds (the *top* coal) in Coalbrooke Dale. It is also found in coal in Flintshire.

Further west, Kingswinford colliery affords only *Anthracosia*, *Modiola*, and the *Gyracanthus formosus*. At Moor Lane, Brierly Hill, the *Holoptychius* and *Lingula*.

Further south, near Oldswinford, White Hall colliery has the usual Brachiopods, *Lingula* and *Discina*, with *Conularia*, *Anthracosia bipennis* (in coal), and the *Aviculopecten scalaris*.

Bare Moor colliery, only Brachiopods, Productæ, &c.

CHAPTER VI.

DESCRIPTION OF THE ROCKS—*continued.*

Detailed Description of the Coal-measures.

1. ***Beds above the Upper Sulphur coal,*** including the Halesowen sandstones and the Red Coal-measure clays.

Wherever the bed known as the Upper Sulphur coal is mentioned in the pit sections, it is found to lie about 300 feet above the Thick coal, and about half that distance above the Two-foot or Little coal. The Upper Sulphur coal is mentioned in most of the pit sections in the latitude of Dudley, from Great Bridge to Kingswinford.

At the Trough pits near Burnt Tree it is 343 feet above the Thick coal, but this thickness diminishes as we come south to about 290 at Corbyn's Hall and Wordesley Bank.

Farther south still, towards Corngreaves and the Hawne the Upper Sulphur coal seems to disappear, but the Two-foot continues, lying at a height of about 150 feet over the Thick coal at Congreaves, at the Old Lion colliery, and at a pit a little north of the Sleck Hillock formerly worked by Mr. Mills.

We may conclude, therefore, that the Two-foot coal will retain this position over all the southern portion of the field, and that the place of the Upper Sulphur coal (whether it be present or absent) will never exceed a height of about 300 feet above the top of the Thick coal.

1*a*. ***Halesowen Sandstones.***—There are beds, however, in which at least one coal occurs, which are much above this height over the Thick coal. A little bed of coal is to be seen in a small ravine nearly due east of Ham House near Old Swinford, in the brooks running down from Lutley to Lutley Mill, in the brooks in Uffmoor Wood, and Mr. Mathews, of the Leasowes, informed me that he came upon a similar little coal in some excavations in the Leasowes demesne. Mr. Richards also formerly sank at Wassel Grove, and passed through two little coals, one of four inches and the other eighteen inches thick. Now the rocks associated with these little coals are principally olive green, brownish, and yellowish sandstones, sometimes pebbly or conglomeritic; and this sandstone group stretches all across the southern portion of the coal-field by Prescott and Wollescote and Careless Green, Wassel Grove, Upper and Lower Lutley, Halesowen, and the Leasowes, and caps the hills of High Haden, Homer Hill, and Cradley Park.

This sandstone group seems to have a thickness of not less than 200 or 300 feet, and from underneath it there appear red and green and mottled clays likewise of considerable thickness, as may be seen by the spoil banks of the pits on the north side of Gosty Hill, and thence at various places north of those just mentioned to Cradley and the Lye Waste and Hay Green.

The little coal or coals which are to be seen high up in the sandstone group have sometimes been spoken of as if they were the representative of the Upper Sulphur, or the Two-foot, or even the Brooch coals. It may be shown by the following facts that this cannot be the case, and that the coal of Wassel Grove, and the other places mentioned above, is far higher above the Thick coal than even the Upper Sulphur coal.

At Mr. Attwood's colliery at Hawn the depth of the shaft to the bottom of the Thick coal is 255 yards = 765 feet; but as the beds dip south at the rate of 3 inches in a yard, and they have driven a "gate-road" in that direction 450 yards without meeting any fault or change of dip, the end of the gate-road must be 112 feet below the bottom of the

shaft. But inasmuch as the surface of the ground rises rapidly to the south, while the beds fall, that rise being at least 100 feet in the 450 yards, we get over the head of the gate-road a thickness of beds above the Thick coal of *not less than* 977 feet.* Let us, then, suppose the beds to be absolutely horizontal from the end of the gate-road to Hasbury Hill, south-west of Halesowen, which those near the surface certainly are for the greater part of the distance, we must still add another 70 feet for the total rise of ground from Hawn to Highfields, Hasbury,† when we shall have a thickness of at least 1,000 feet between the uppermost beds seen there and the *top* of the Thick coal.

The details of the beds passed through in the Hawn shaft are not known, but the high ground on all sides of it is composed of greenish brown sandstone, dipping generally at a very gentle angle to the south. In the lane leading from Hawn to Gosty Hill, these sandstones are conglomeritic, and many of the pebbles consist of fragments of trap, not, however, of basalt or greenstone, but of brown and purple porphyry (or felstone) very like some of those so abundant in the Permian rocks of the Clent Hills. It appears, therefore, that fragments of such rocks began to be drifted from some rather distant locality even during the Coal-measure period.

These beds and those quarried near Halesowen are probably below the sandstones of Lutley and Wassel Grove, in which the little beds of coal before mentioned occur, for the places where these coals occur are both further south and on higher ground than that round Hawn and Halesowen.

Mr. G. Thompson, formerly manager of the British Iron Company's Works at Corngreaves, communicated the following section of the pit sunk at Wassel Grove.

	FT.	IN.
1. Sand rock and other rocks	123	0
2. Blue rock-binds	4	0
3. Sand rock	38	0
4. Little coal	0	4
5. Blue rock with black shades	5	0
6. Grey peldon	0	8
7. Rock binds	2	0
8. Rough mingled rock	13	0
9 Blue rock	4	0
10. Fire-clay	6	0
11. Soft white rock	13	0
12. Bind measures with two ironstone bands	4	0
13. Coal	1	6
14. Fire-clay	4	0
15. White rock	15	0
16. Mingled ground with binds	5	0
17. Rock with sheds (bored into)	45	0
	283	6

* To the original 765 feet we must add 112 for the fall of the beds, 100 for the rise of the ground = 977 feet: deducting 30 feet for the thickness of the coal, we get in round numbers 950 feet for the thickness above the coal.

† The Hawn pits are 370 feet above the sea. Captain Ibbetson made the spot at "H" of "High fields" in the Ordnance map 540 feet above the sea; difference =170 feet.

From the preceding considerations it is scarcely possible that the place of the Thick coal can be at a less depth than 800 or 900 feet (say 300 yards) beneath Wassel Grove, and all the line of country mentioned before where these little upper coals are observed to crop out.

1*b*. *Red Coal-measure Clays.*—These facts are represented in Horizontal Section No. 10, sheet 25, which was taken over Hasbury Hill, where there is a capping of red rock believed to be Permian, and thence across Hawn to the Old Lion colliery. In the latter shaft (of which a vertical section is given on Sheet 18 of the Vertical Sections, No. 25) there are about 50 or 60 feet of dark and grey rocks at the top containing a little nine-inch coal, underneath which come about 280 feet (or 93 yards) of red and blue marls, interstratified with "blue ground," "blue rock," and "mottled ground," many of the so-called blues being rather green than blue, but the predominating colour of the whole a deep purplish red. The bottom of this red group is about 233 feet (or 77 yards) above the Thick coal. A similar group of red and blue beds, mostly clays, but sometimes sandy, is noted in the sections at Congreaves and Baremoor. Red and blue mingled ground is mentioned in the Barrow Hill pit (No. 23, Sheet 18, of Vertical Sections,) in the shafts about Corbyns Hall, at Wordesley Bank, and almost wherever a detailed section is given of the beds lying 100 yards or so above the Thick coal in the southern part of the district.

North of Dudley, again, in the Trough pits at Burnt Tree, where the Thick coal is 617 feet deep, the upper 360 feet are said to consist largely of "mottled ground," "mingled ground," "blue and mingled ground," the "mottling" and the "mingling" almost always alluding to the occurrence of red with the other colours, and the term "ground" signifying an argillaceous material, and not a sandstone (see Vertical Section No. 14, Sheet 17). These reddish clays are worked in large excavations at the surface near Tipton and south of Oldbury, as well as between the Lye Waste and Stourbridge, and used for making a very superior kind of brick, generally of a deep blue colour. In the deep sinking at Great Bridge, near West Bromwich, where the Thick coal is 567 feet deep, there is a bed of "red marl" 6 feet thick, at a height of 205 feet above the Thick coal; and 38 feet above that again, or about 243 feet (or 80 yards) above the Thick coal, there is a group of red marls 64 feet thick, with a few beds of "blue" or "mottled rock." The Upper Sulphur coal then comes in with a "white fire clay" below and a "blue clunch" above, covered by about 63 feet of beds containing no red, over which are 192 feet of other measures, in which beds of "red marl" 8 to 16 feet in thickness, are very frequent.

We may, therefore, assume it as a fact, supported by all the available evidence we possess, that there was deposited a group of beds in the South Staffordshire coal-field lying about 100 yards above the Thick coal, being themselves about 100 yards in thickness, and principally composed of red or red and green (or blue) clays, variously interstratified with beds of other colours, and occasionally containing small coals, fire-clays, &c.

This fact is very important, for it enables us to classify some beds in the northern part of the district in their right place as Coal-measures, notwithstanding the red colours which formerly led us to look upon them as belonging to the Permian (or even, still earlier, to the New red) formation. These are the red clays about Walsall Wood,* those of

* Professor Ramsay and Mr. Hull have lately (February 1859) gone over this ground again for the express purpose of comparing these several localities with each other, and with the red beds in the southern part of the coal-field, and have satisfied themselves that they all belong properly to an upper part of the Coal-measure series.

Essington Wood, those of Rumour Hill near Cannock, and of Littleworth on Cannock Chase. They are largely opened for brick pits, the bricks being hard blue bricks of a superior quality and peculiar appearance. The beds in those northern localities consist principally of dark purplish-red clay, mottled and streaked occasionally with green, and interstratified not unfrequently with soft reddish or brown sandstones. They appear to constitute a group of very considerable thickness, since they have been sunk through for more than 200 feet at the Coppy Hall colliery, just at their edge, and have probably a total thickness of at least double that. They are nowhere known to be covered, in the northern part of the coal-field, by any group of greenish or brownish sandstone, as they are near Halesowen and the neighbourhood, but possibly they may have been so originally, after having, like the other coal-measures, swelled out to a greatly increased bulk on the north over that which they possessed on the south side of the district.

Having thus traced the beds over the Upper Sulphur coal, together, perhaps, with some of those in which it lies over the whole coal-field, we will now turn to the detailed descriptions of the beds mentioned in the first general section given at page .

2. *The Upper Sulphur Coal.*—The Upper Sulphur coal is itself a small and insignificant bed, rarely if ever exceeding 1 foot 6 inches in thickness; it has never been "gotten," nor would it be worth the trouble of extracting. Like most other small coals, it is local only, and is altogether wanting in some shafts that go through the beds in which it is found at other places.

3. *Intermediate Measures.*—The intermediate measures, between the Upper Sulphur coal and the Two-foot, have a mean thickness of about 150 feet, which thickness, wherever the two coals are undoubtedly present, does not seem to vary more than 37 feet. The variations in thickness seem to be due to the greater or less abundance of sandstones. The beds are chiefly argillaceous, being designated usually by the terms "bind," "clunch," "ground," "fire-clay," &c., but having several interstratified beds of various kinds of "rock" or sandstone. Like the beds before described, as we go south the sandstones begin to thicken and predominate, and become in some instances conglomeritic.

4. *Little or Two-foot Coal.*—Although this coal has never been worked or "gotten," its thickness not being sufficient to allow it to be got with profit, it is yet a very persistent bed, as its presence is noted in all the detailed pit sections we have which pass through its place. It varies from 1 to 2 feet thick, but I know nothing of its quality, nor whether any trials of it have been made.

5. *Intermediate measures between the Little coal and the Brooch.*—These beds are almost universally clunch, binds, fire-clay, or some argillaceous material; but in one or two cases they contain beds of rock or sandstone. Their thickness in all the central portion of the field varies from 13 to 48 feet, the mean being about 25 feet. As we go south and west, however, into the district of Congreaves, Cradley, and the Black Delph, the thickness of these beds rapidly diminishes, and they vary only from 2 to 7 feet, consisting of fire-clay or batt, or both. In some places in the neighhourhood of Kingswinford, as also in the district last referred to, a little coal makes its appearance occasionally in these beds, but is too unimportant to require a separate notice.

6. (I.) The Brooch Coal.*—This is the uppermost workable coal in the coal-field; it is almost invariably of excellent quality, and in

* Sir R. I. Murchison, in his account of this district in the "Silurian System," derives this word from the measures having been first "broached" or entered on by this

great request in the district for parlour fires. It varies in thickness from 2½ to 6 feet, the mean and by far the most usual thickness being about 4 feet. It is quite constant over the whole coal-field, wherever the beds occur in which it ought to be found.

7 and 8. (*I.* 1.) ***Brooch binds ironstone measures and Herring coal.***—These beds are almost entirely confined to one portion of the district, that, namely, on the west and south of Dudley. The Brooch binds are shales averaging about 7 feet in thickness (Vertical Sections, sheet 26, No. 49). In some places, as at Corbyns Hall, and Bromley Hall near Kingswinford, as also in the Corngreaves district, they contain ironstone nodules, which sometimes, but not always, are worth getting. About Brierly Hill and at Wordesley Bank Colliery they thicken out to upwards of 20 feet, and contain good ironstone. The Herring coal is generally about 18 inches thick, and not worth getting; it is, however, very persistent in the district now described, and as we go towards High Haden we find other small coals, one of which is a cannel coal, coming in just below the Herring. Neither of these measures are mentioned in the section of the Oak-farm pit, nor in the borings at Holbeche Mill near Himley, on the west side of Dudley, nor do they occur at all on the east side of Dudley, except in one part of Tividale, where, in the record of an old sinking in 1797, given in Plott's History of Staffordshire, I find mentioned the following beds:—

	FT.	IN.
a Brooch coal - - -	3	9
b Black clunch - - -	7	0
c Coal - - - -	1	3
d Pennyearth with ironstone -	7	0

of which *b* and *c* must be the beds we are speaking of.

9. (*I.* 2.) ***The Pins and Pennyearth ironstone measures.***—These take their names from the form of the ironstone nodules which they contain, the Pins being small cylindrical nodules, and the Pennyearth small round flattish nodules, like penny pieces. These measures have a wider spread than those last mentioned, since they are noted in sections east of Dudley, not only at Tividale but at Burnt-tree and Tipton, as also at Oldbury, in which last two places a small coal called Pennycoal, about a foot thick, is sometimes found in them. Their thickness there is from 7 to 20 feet. I do not know how far these beds may have extended and been formerly worked for ironstone in the central portion of the coal-field between Dudley and Bilston, but they are now principally, if not solely, gotten in its south-western portion between Dudley and Stourbridge, especially in the district around Corbyn's Hall and Brierley Hill, where they sometimes together attain a thickness of 27 feet; and at Wordesley Bank Colliery (Vertical Sections, sheet 18, No. 35) the Pins are 4 feet, and the Pennyearth 27 feet thick. They always occur also in the Corngreaves district, where they vary in thickness from 6 feet to 17 feet. It appears that the two measures not always distinctly recognizable, as sometimes one sometimes the other only is mentioned; and moreover, that the presence of good ironstone is uncertain, so that in some instances where the measures exist they are not worth working, and therefore but little noticed. They are not mentioned at all in the sections of Holbeche Mill and the Oak-farm on the one side, nor at

coal. Historically, I believe this was not the fact, as the first working seems to have been along the crop of the Thick coal. I venture to conjecture that the name is derived from the old-used word "broche," a spit, as this coal makes an excellent fire for roasting at.

Netherend near Cradley on the other side of the south-western district; nor do I find them mentioned by name in the sections about Highfields and Bradley south of Bilston, nor in those of Great Bridge and the Swan towards West Bromwich. In some sections, however, as in the old one of Bradley mine, beds containing ironstone are mentioned as occurring a short distance below the Brooch coal, which are probably these measures.

10. *Intermediate measures, containing the Thick-coal rock.*—These measures, according to the details given in thirty-five pit sections, vary greatly, not only in widely separated parts of the coal-field, but often in places immediately adjacent to each other.

In part of the country just south of Bilston the question is complicated by the occurrence of the "Flying reed," which will be described presently. Supposing this Flying reed to be the top beds of the Thick coal, we have here only 90 feet between it and the Brooch, occupied entirely by "blue binds," while in the beds interposed between the Flying reed and the remainder of the Thick coal there occurs a rock or sandstone of considerable thickness. In the district east of Kingswinford, where the phenomenon of the Flying reed again occurs, we have the recurrence of similar facts.

Setting those exceptional cases aside, we have at Bradley about 60 feet of beds between the Brooch and Thick coals, of which the uppermost portion is clunch and rock binds, with ironstone, the lower, peldon and grey rock, 27 feet thick; while around Tipton, Burnt-tree, Tividale, Great Bridge, Oldbury, and West Bromwich, there is an average thickness of between 120 and 130 feet for these beds, the greatest thickness being 170 feet and the least 83 feet. Of this thickness 75 feet on an average is composed of "rock" or sandstone, the greatest amount of that material being 120 feet and the least not more than 20 feet. The method of its occurrence varies as much as its amount, as it is interstratified with more or less argillaceous materials in every possible way, except that the sandstone seems most generally to preponderate in the lower part of the mass.

In the south-western portion of the district the thickness of these beds also varies considerably. In the mines around Pensnett, Corbyns Hall, and Shut End, their total thickness varies from* 52 feet to 116 feet, the average being 85 feet. In those around Corngreaves (or between the Lye Waste and Rowley Regis) the least thickness is 109 feet, the average rising to 125 feet, while the greatest I know is 157 feet. Around Brierley Hill, on the contrary, and at Wordesley Bank and the Black Delph, the greatest thickness of these beds is diminished to 52 feet, they are sometimes as little as 38 feet, the mean being only 46 feet. In each of these cases the thickness seems to vary almost directly as the quantity of "rock" or sandstone. In the Congreaves district the whole of these beds are almost entirely composed of rock and rock binds. Around Brierley Hill there is not more than 6 feet to 12 feet of rock, while round Corbyns Hall the quantity of rock is generally about half the whole mass, being more or less interstratified with beds of binds or clunch, which are generally described as "strong," meaning that the argillaceous is largely mingled with arenaceous or siliceous material. I do not know that any of these beds have acquired distinctive names, except that occasionally I have found near the bottom of them mention made of "Shooter's four measures," or "Shooter's greys."

* Still exclusive of those mines in which the Flying reed occurs, when the thickness sometimes diminishes to 29 feet.

11. (*I.* 3.) ***Broad earth, Catch earth, and Batt, containing the Ten-foot and Backstone ironstones in the Pensnett district.***—I do not know why the first is called "broad"; "catch" earth, I presume, is so-called because immediately under it they catch the coal, but I have sometimes seen it written "cat earth," or rather "cat heath." These are beds known to the miners, and to them only, as they can only be seen while a shaft is being sunk, and then only just while it is passing through them. They are, I believe, earthy shales of a peculiar character. I have had them described to me as "clunchy stuff," and in other similar terms. They do not appear to be always present, or if so their presence is not always noted in the sections. Where they do occur, however, they are said to be always recognizable by their peculiar character. The total thickness of all three beds seems never to exceed 12 or 14 feet, the most usual numbers being 6 or 8. The "black batt," or hard bituminous shale, is generally about one foot thick, and rests directly on the upper surface of the coal; this seems to be almost invariably present even when there is no mention made of either of the other two beds. In the neighbourhood of Brierley Hill, and some other places, beds in this position, if not these beds, contain ironstone, the lowermost of which is called Backstone, and is found in shale immediately above the coal. The other is called Ten-foot stone, from its being found at that distance above the top of the Thick coal.

In the old Tividale section, mentioned before, the beds immediately above the Thick coal are as follows:—

	FT.	IN.
a Clunch and ironstone - -	2	9
b Black batt - - -	6	0
c Coal - - - -	0	6
d Catch earth - - -	2	9
e Batt - - - -	7	0
f Thick coal - - -	31	6

In a section at Great Bridge, communicated by Mr. W. Matthews, I find these beds:—

	FT.	IN.
a Coal and batt - - -	15	0
b Blue rock - - -	16	0
c Thick coal - - -	32	0

a and *b* being the most anomalous beds to rest on the Thick coal of which I have seen any account.

12. (II. to XV.) THE THICK COAL.—We come now to the description of a set of beds of high interest and importance both to the practical miner and the theoretical geologist. To the latter the careful study of these beds would, I believe, afford many materials for arriving at a better understanding of the question of the origin of coal in general than he now possesses. Some of these materials I may be enabled to lay before him.

The "Thick coal" consists of a number of beds of coal, varying from 8 or 10 to 13 or 14, resting either directly one upon the other or separated by thin seams of "shale," or "clunch," called "partings." Each of these beds of coal is known to the miners by a particular name, and each has so much of a peculiar character that a block of it can be at once recognized by an old "thick-coal collier," and referred to its particular bed. This peculiarity of character in the different beds seems to extend over the whole of the Thick coal district, but whether the beds retain their peculiarities where they cease to form the Thick coal I am not aware. It would be a curious experiment for any one prac-

tically acquainted with the Thick coal to see whether any of the beds of Essington or Wyrley could be identified with any of those of the Thick coal by their lithological characters.

As good typical sections of the "Thick coal" I will, first of all, give two, taken from the central part of the district, one of the Claycroft colliery, at the Foxyards, about two miles north of Dudley, communicated by Mr. R. Smith from Lord Ward's office; another, the old sinking in 1797, at Tividale, one mile east of Dudley, taken from Shaw's History of Staffordshire, in which a very good account of the coal-field was given by Mr. Keir.

Foxyards.	Ft. In.	Ft. In.	Tividale.	Ft. In.	Ft. In.
1. Roofs coal	- -	4 6	1. Roof, or top floor	- -	4 0
Batt	0 9	–	Parting, soft dark earth	0 4	–
2. Top slipper	- -	2 6	2. Top slipper, or Spires	- -	2 2
Batt	0 7	–			
			3. Jays coal	- -	2 0
3. White coal	- -	3 9	White stone parting	0 1	–
			4. Lambs coal	- -	1 0
4. Tow* (tough) coal	- -	4 6	5. Tow (tough) or Heath	- -	1 6
			6. Benches† coal	- -	1 6
5. Brassils‡ coal	- -	1 6	7. Brassils or Corns coal	- -	1 6
Batt	0 3	–	Foot coal parting	0 4	–
			8. Foot coal, or Bottom slipper	- -	1 8
6. Foot coal	- -	2 0	John coal parting	0 1	–
Batt	0 3	–	9. John coal, or Slips, or Veins	- -	3 0
7. Slips coal	- -	3 9	Hard stone	0 10	–
Hard stone	0 7	–	10. Stone coal, or Long coal	- -	4 0
8. Stone coal	- -	4 6	11. Sawyer, or Springs	- -	1 6
9. Sawyer§	- -	2 9	12. Slipper	- -	2 6
10. Slipper	- -	3 9	Humphrey parting	0 1	–
Batt	0 6	–			
11. Benches‖ coal	- -	3 0	13. Humphreys coal	- -	2 3
	2 11	36 6		1 9	28 7
Total, with partings	- -	39 5	Total, with partings	- -	30 4

A few years ago the unusually thick coal at Foxyards was worked by "open work," as it there "cropped out" to the surface, and was got out from a large quarry, exposing a cliff of coal 40 feet high and about 100 yards in length.

In Shaw's History of Staffordshire Mr. Keir gives the following account of the qualities of the different beds of the Thick coal near Tividale :—

"There is a considerable difference in the quality of the different beds or measures of the main coal. The first or upper bed called the Roof floor is generally left as a roof to support the earth or clunch above

* Pronounced to rhyme with "cow."

† This coal is but rarely noted; there is in many sections a coal called "fine floors," between the "white coal" and the "tow or heath."

‡ "Brassil" is a term generally used to denote a rough impure coal; sometimes it seems as if used to denote the presence of much iron pyrites, and to mean therefore "brassy"; it is not, however, always used in that sense.

§ There is very frequently another coal called "Patchells," especially on the west of Dudley over the Sawyer.

‖ This lowest coal is known by the various terms of Humphreys or Omfray floor, benches, holers, kit, kid, or kick coal, and red coal.

it from falling. The second bed, called the Top Slipper, and the third and fourth beds, which together are called the White coal, are reckoned the best for chamber fires. Next to them in goodness are reckoned the eleventh and twelfth beds, called Sawyer and Slipper. After them come the eighth, ninth, and tenth, called the Foot coal, Stone coal, and John coal. The Tows and Benches are preferred for making the cokes with which iron ore is smelted, and therefore are generally reserved for the furnaces. They do not kindle a flame so vividly as some of the foregoing measures, but they give a more durable and stronger heat. These two measures contain the largest proportion of fibres resembling charcoal. The part of the Brassil measure which contains pyrites is generally laid aside, or used only for burning bricks or lime. The Humphries, being the lowest measure, is that which is cut away in order to let those above it fall down, and, therefore, most of it is reduced to the small coal called sleck."

Proceeding from this central portion of the district, in every direction, we find several minor changes taking place in the constitution of the Thick coal. The individual beds, even where they are all present, vary frequently in thickness, and often in quality, in such a way, however, as to maintain the mean aggregate thickness of 30 feet over by far the greater portion of the district.

There are much more remarkable variations to be now noticed. In by far the larger portion of the extent of the Thick coal we find the upper beds consisting of—

1. Roofs, varying from 2 to 4 feet.
2. Top slipper or spires, varying from 2 to 3 feet.
3. White coal, generally about 3 feet.

Or sometimes the "Roofs" only is mentioned above the "White coal," with a thickness of 3 or 4 feet. If, however, leaving the central part near Dudley, we go towards the district between Bilston and Wolverhampton, we shall find the "White coal" forming the upper bed of the "Thick coal," and we shall get above it a separate bed of coal more or less removed from the "Thick coal," under the name of the "Flying reed coal." At Deepfields, near Coseley, we get the following section :*—

	FT.	IN.	
Flying reed coal	4	0	
Blue binds	54	0	84 feet.
Rock	30	0	
White coal	3	0	

under which come the "Tow," "Brassil," and the other measures of the Thick coal.

At Highfields, nearer Bilston, we have† (Vertical Sections, sheet 26, No. 51)—

	FT.	IN.	
Flying reed coal	3	6	
Sundries	54	0	
Do.	30	0	204 ft. 3 in.
Do.	89	11	
Rock	30	4	
White coal	3	0	
Tow coal	2	0	
&c.	&c.		&c.

* Taken from the "Miner's Guide," published by Mr. T. Smith.
† From Smith's "Miner's Guide."

We thus get the top beds of the Thick coal separated from the rest by 84 feet in one case, and 204 ft. 3 in. in the other; the interposed materials consisting of clay and sandstone. North of Highfield there is no mention at all of the Flying reed, it having either cropped out altogether, or been thrown out by the great Lanesfield fault.

Between Bilston and Wolverhampton, the "White coal" is always looked on as the top of the Thick coal. Here, however, we get still another change in the *central* part of the Thick coal, as a considerable mass of shale, sometimes containing ironstone, is interposed between the "Foot coal" and the "Slips coal."* This mass of shale, which goes by the euphonious appellation of "Hob and Jack," is 7 feet thick at Bradley Lodge just south of Bilston, and 10 feet at the Walling pits near Stow Heath, and at Ettingshall Lodge Colliery. There is exhibited in these facts that tendency in the Thick coal to split up towards the north, which has been already commented on in the general description of the Coal-measures.

If now we proceed from the neighbourhood of Dudley towards the west, we meet with very similar facts.

In going from Dudley to Kingswinford we find the Thick coal preserving a great uniformity of character for nearly three miles, varying but little from the following section:—

SECTION in the Horse-pasture, Corbyn's Hall.†

	FT.	IN.	FT.	IN.
1. Roofs coal			3	2
White coal parting‡	3	6		
2. White coal			3	9
3. Floors coal and batt			1	6
4. Heath or tow coal			3	6
5. Brassils coal			1	6
6. Fine coal			2	6
7. Veins coal			1	6
Stone coal parting	0	8		
8. Stone coal			3	0
9. Patchell's coal			1	0
10. Sawyer coal			2	0
12. Slipper coal			3	0
12. Benches or kid coal			2	5
	4	2	28	10
Total, with partings			33	0

A little north of Corbyns Hall, namely, at Shut End Colliery, and thence towards Kingswinford on the west, and Oak-farm on the north, we find a recurrence of the phenomenon of the "Flying reed" similar to that just noticed towards Bilston and Wolverhampton.

At the Dairy-pit in Shut End Colliery we have the Flying reed coal 4 feet thick, resting directly on the White coal 3 feet thick, with the remainder of the Thick coal beneath it, forming a total thickness of solid coal 29 feet 4 inches, with only one 3-inch parting above the

* See Vertical section, sheet 17, comparative sections of Thick coal at the bottom of the sheet, and sheet 18, No. 32.

† Supplied by Mr. W. Matthews.

‡ In other places, however, as at Dudley Woodside, &c., this "white coal parting" does not exist, and No. 1 rests directly on No. 2.

"stone coal." Proceeding to No. 5 pit, about 100 yards south of the Dairy-pit, we get—

	FT.	IN.	FT.	IN.
Flying reed coal - -	-	-	4	0
Soft shaly parting	- 10	6	–	
Thick coal - -	-	-	25	4
	10	6	29	4

All the coals having exactly the same thickness as at the Dairy-pit, but 10½ feet of shale being interposed between the first and second. About 120 yards west-south-west of No. 5 pit we get at the new Engine pit—*

	FT.	IN.	FT.	IN.
Flying reed coal - -	-	-	4	8
Strong binds -	- 5	4	–	
Dark clunch -	- 2	3	–	
Mild clunch -	- 24	8	–	
Dark shady clunch	- 6	6	–	
Thick coal - -	-	-	22	6
	45	9	26	2

And at another pit 60 yards farther from No. 5, in the same straight line, we have—

	FT.	IN.	FT.	IN.
Flying reed coal -	-	-	4	4
Mild clunch	- 29	2	–	
Dark shady clunch	- 26	2	–	
Thick coal -		-	24	3
	55	4	28	7

At Kingswinford, half a mile farther west, we get†—

	FT.	IN.	FT.	IN.
Flying reed coal - -	-	-	3	0
Sundry measures -	- 128	0	–	
‡ Thick coal - -	-	-	22	8
	128	0	25	8

While at Oak-farm Colliery, about half a mile north-north-west of Shut End, we have §—

	FT.	IN.	FT.	IN.
Flying reed coal - -	-	-	2	6
Strong binds -	- 67	0	–	
Rock (sandstone) -	- 51	0	–	
Thick coal - -	-	-	24	0
	118	0	26	6

* The details of the Shut End Colliery were supplied to me by Mr. Colly, ground bailiff to Mr. Foster.

† From Lord Ward's office.

‡ This Thick coal has many small partings between its beds.

§ Supplied by Mr. Growcott, ground bailiff.

Fig. 4.

The facts stated above are represented in Figure No. 4, in which the original relative positions of the coals are drawn with as close an approximation to accuracy as the materials will allow.

At two pits, sunk since the first edition of this Memoir was published, of which the sections have been communicated by Mr. Beckett, of Wolverhampton, who obtained them from Mr. Growcott, the following facts are noticeable :—

No. 1. Round Hill pits, near Fir Tree House,* Himley,—

	FT.	IN.	FT.	IN.
Flying reed coal - -		-	2	3
Fire clay, &c. - -	8	3	–	
Strong dark binds -	29	0	–	
Binds and peldon -	25	3	–	
Rock and peldon -	46	6	–	
Thick coal (with partings) -		-	39	2
	109	0	41	5

No. 3. Pit of Himley Colliery, a little south of the pit above,—

	FT.	IN.	FT.	IN.
Flying reed coal - -		-	2	6
Fire clay - -	5	0	–	
Rock binds and peldon -	110	6	–	
Thick coal - -		-	24	6
	115	6	27	0

It is very remarkable that there seems to be no corresponding addition to the height of the Brooch coal above the remainder of the Thick coal in these cases ; but as the thickness between the Flying reed coal and the remainder of the Thick coal increases, that between the Flying reed and the Brooch diminishes in nearly the same ratio. Where, for instance, the Flying reed is only 10 feet 6 inches above the rest of the Thick coal, the Brooch is 95 feet above the Flying reed, but it is only 30 feet above it in the last section given above, where the latter is 115 feet above the rest of the Thick coal.

It is farther remarkable that both on the north and on the west where this Flying reed makes it appearance there is a simultaneous change, not only in the grouping, but in the nature of the beds between the Brooch and it. Wherever the Thick coal remains entire, there is a sandstone known as the Thick-coal rock above the Thick coal and between it and the Brooch. When, however, the Flying reed has attained any height above the Thick coal, there is no sandstone between it and the Brooch, but sandstone (or rock) is found underneath the Flying reed between it and the rest of the Thick coal.

It appears, then, notwithstanding the inclined position of the

* See Vertical Section, No. 48, sheet 26.

Flying reed with respect to the Thick coal, that the Brooch remains nearly parallel to the latter, so that we have the three principal coals, the Heathen, the Thick, and the Brooch, retaining their parallelism, while the Flying reed or top part of the Thick lies obliquely between them, separating from each other two similar groups of sandstone beds, one above it and the other below it, these sandstones being nearly on the same horizon, but clearly not contemporaneous with each other.

To the south of the Shut End and Kingswinford district, the measures rapidly resume their normal condition, as represented in the Corbyns Hall section given above. That section may be taken as a sufficiently close description of the Thick coal over all the district between Kingswinford, Dudley, and Halesowen, allowance being made for frequent slight variations in the thicknesses of the different beds of coal and of the partings between them.

As we go down to the Lye Waste, however, near Stourbridge, and approach the south-western boundary of the coal-field, we find a very remarkable change takes place in the character of the Thick coal in that direction, as it loses all its generally distinctive features and assumes those of the following section taken at Tintam Abbey fire-clay works :*—

	FT.	IN.	FT.	IN.
1. Top coal			7	0
Spoil (shale, &c.)	5	0	–	
2. Middle coal			6	0
Spoil (shale, &c.)	5	0	–	
3. Bottom coal			6	0
	10	0	19	0
Total, with partings			29	0

Here, then, as before, we find a tendency in the Thick coal to split up into several groups of beds, although here that tendency is produced by a thinning and diminution in the coal itself, and its replacement by earthy beds, and not as before by a mere separation of the beds by additional beds of shale or sandstone.

About a mile to the eastward of Tintam Abbey, at the Hayes colliery, the Thick coal was found to have the following section, communicated by Mr. T. King Harrison, who also informed me, that farther south the coal became so bad and rubbishy as not to be worth working.

Section of the Thick coal at the Hayes colliery, near Lye Waste :—

	FT.	IN.	FT.	IN.
1. Six inch coal			0	5
2. Roofs coal			2	0
3. Spires coal			3	0
4. White coal			3	6
Dirt	2	0	–	
5. Heath coal			4	0
Dirt	5	0	–	
6. Brassils			4	0
Dirt	4	0	–	
7. Fine coal			3	0
8. Stone coal			1	0
9. Foot coal			1	6
Dirt	1	0	–	

* Supplied by Mr. Skidmore, of Amblecote.

	FT.	IN.	FT.	IN.
10. Patchells coal - -		-	2	6
Dirt - - -	1	0		–
11. Sawyer coal - -		-	2	3
Dirt - - -	5	0		–
12. Slipper - - -		-	3	0
	18	0	30	3
Total, with partings - -			48	3

From the frequently high inclination of the beds at the Hayes, it is possible that some deduction must be made from the thicknesses given above, so as to bring them more in accordance with the thickness found in other pits in the neighbourhood. Still the section is good so far as showing the separation of the coals, in which it agrees with the section of the pits at the Hawn colliery, which are the farthest pits towards the south-east that have been opened. It will be seen that at the Hawn colliery the Benches coal is only 6 inches thick, while that bed is absent altogether at the Hayes, where, however, its absence is compensated for by the appearance of a little six inch coal, above the ordinary Roof coal.

The Hawn Colliery.*

	FT.	IN.	FT.	IN.
1. Roof coal - - -		-	1	6
2. Spires, or spin coal -		-	2	7
3. White coal - -		-	3	0
Parting - - -	2	0		–
4. Heath or tow coal -		-	3	0
5. Brassils coal - -		-	1	6
Parting - - -	3	0		–
6. Stone coal - - -		-	3	0
Parting - - -	1	0		–
7. Patchells coal - -		-	1	6
Parting - - -	0	8		–
8. Sawyer coal - -		-	1	6
9. Slipper coal - -		-	3	C
Parting - - -	1	6		–
10. Benches coal - -		-	0	6
	8	2	21	1
Total, with partings -		-	29	3

A very similar section to this, except that the partings are hardly so large, is that of Mr. Mills's colliery, about one mile north-by-east of Hawn, just under the "B." of "Black Heath," in the Ordnance map. Mr. Mills gave it me as follows:—

	FT.	IN.	FT.	IN.
1. Roofs coal - -		-	1	6
2. Spires coal - -		-	2	9
3. White coal - -		-	3	0
Parting - -	0	9		–

* Communicated by Mr. T. A. Attwood.

	FT.	IN.	FT.	IN.
4. Fine floors coal - -		-	1	4
5. Tow coal - - -		-	3	0
6. Brassils coal - -		-	1	6
Parting - - -	0	6		-
7. Fine coal - - -		-	2	9
Parting - -	2	0		-
8. Veins coal - -		-	2	0
9. Stone coal - -		-	3	0
Dunjack, hard parting -	0	6		-
10. Patchells coal - -		-	2	9
Batt - - -	0	4		-
11. Sawyer coal - -		-	1	4
12. Slipper coal - -		-	4	3
13. Benches coal - -		-	1	6
	4	1	30	8
Total, with parting -		-	34	9

Now, about three quarters of a mile east-south-east of the latter place, there was a deep pit sunk some years ago by the Rev. E. Dudley, and the place was called the Black Heath colliery. The section of this pit was communicated to me by Mr. Benjamin Gibbons, of Shut End House, and is drawn in the 18th sheet of Vertical sections, No. 23. In this section they found the beds above the Thick coal in regular order, but thin and poor, the Brooch coal, for instance, being not more than 9 inches or 1 foot thick, instead of 3 or 4 feet. They passed through the Broad earth and Catch earth, the usual measures above the Thick coal, but below them they found—

	FT.	IN.
1. Soft parting - - -	1	0
2. Black batt - - -	6	0
3. Bad and rubbishy coal -	7	5
4. Good coal - - -	3	0
5. Brown batt and rock - -	10	0
6. Ditto, with ironstone balls -	4	3
7. Batt - - - -	0	9
8. Coal - - - -	2	0

Of this section 3 and 4 must be taken to represent the Thick coal, 6 the Gubbin measures, and 7 and 8 the Heathen coal, hereafter to be described. Mr. W. Matthews informed me that he drove out gate-roads and headings towards Cakemoor in various directions and for considerable distances from this shaft without being able to find anything of more value or importance. We have here, then, the appearance of a great change and deterioration in the Thick coal, as indeed in the productiveness of the whole series, towards the south-east, proceeding from Dudley as a centre. If again we started from the neighbourhood of Oldbury, where the Thick coal beds have their normal character, we should find, as we proceeded to the south, towards this same Blackheath, that there is likewise a gradual thinning out of the Thick coal. At Mr. Chance's, No. 2 pit, between Park House and Titford reservoir, the Thick coal is only 27 feet thick, and it was said, when worked, to have thinned rapidly out towards the great boundary fault on the east, to only 7

feet, and even less.* Again, at Birchy-field colliery, between Portway Hall and Titford reservoir, the Thick coal is only 21 feet thick, the whole number of beds being described as present, but each a little thinner than ordinary; and further south, near Titford reservoir, the Thick coal was said to end altogether, either by gradual thinning or by the interposition of sandstone and shale beds.

At the time when the first edition of this Memoir was published the above was all the intelligence that could be procured as to the south-eastern corner of the coal-field. Several subsequent explorations, however, have been made which I was able partially to examine in 1858.

In the first place, Dr. Percy's workings in the Thick coal at the Grace Mary colliery, on the north slope of the Rowley Hills, near Lye Cross Farm, have been continued towards the south, or towards the ground where the basalt appears at the surface. The Thick coal in that direction was greatly deteriorated, and its value almost altogether destroyed, by two circumstances, first by its place being largely occupied by white sandstone, which was deposited together with it; secondly, by veins of trap having been subsequently intruded into it. The sandstone thus contemporaneously deposited with the Thick coal, or instead of it, is spoken of sometimes as "rock and rig," and sometimes as a "rock fault." It will be presently described under the latter designation. The trap veins will be also described under the head of Igneous rocks.

In the colliery belonging to Messrs. Bagnall, adjacent to Dr. Percy's, similar or even greater deterioration of the Thick coal was said to occur.

In the district south of Portway Hall some pits have recently been sunk for Lord Ward. One of these is at Ramrod Hall, a little east of Rowley Regis, just where the W. of "White Heath Gate" is engraved on the Ordnance map. In this pit the following section was found, as communicated by Mr. Spence :—

	FT.	IN.
†1. Binds, marl, rock, &c. - - -	381	0
2. Coal (Two-foot?) - - - -	1	9
3. Black ground and fire-clay - - -	10	3
4. Brooch coal and batt - - -	1	0
5. Blue binds and sand rocks - - -	124	0
6. Broad earth - - - - -	3	0
7. Black batt - - - - -	1	0
8. Thick coal (mingled with sandstones) -	4	0
9. Gubbin measures and Heathen coal mixed with sandstone) - - - -	5	0
10. Rock and rock binds - - -	16	9
11. White ironstone measures - - -	2	0
12. Binds with a Stinking coal - - -	5	9
	555	6

At a distance of 70 yards to the eastward of this shaft the Thick coal was found instead of 4 feet to be 26 feet thick, but "to contain several layers of thin rock."

* This information was communicated by Mr. Aaron Peacock.

† For whole section, see Vertical Sections, sheet 26, No. 47.

Other shafts have been worked and Thick coal gotten south of Titford reservoir, but it all seems very subject to be more or less deteriorated by interstratified layers and irregular beds and cakes of sandstone. At Messrs. Harper and Moore's pits, at Causeway Green, the Brooch coal was found with a thickness of 2 feet 3 inches, and the Thick coal was found below at a depth of about 170 yards (510 feet) from the surface, lying regularly and horizontally with the following as its general section, as given me by Mr. Green, on the spot.

Causeway Green Colliery, Messrs. Harper and Moore :—

	FT.	IN.	FT.	IN.
1. Roofs coal - -		-	1	8
2. Top slipper coal - -		-	2	0
3. Jay's coal - -		-	2	0
4. Lamb's and Tow coal -		-	4	0
5. Brassils coal - -		-	3	0
6. Top foot coal - -		-	1	4
7. Bottom foot coal - -		-	0	7
Loamy parting - -	2	0	–	
8. Slipper or Slips coal -		-	1	0
9. Stone coal - -		-	2	3
10. Patchell's coal - -		-	1	4
11. Sawyer coal - -		-	4	0
12. Benches - - -		-	2	0
	2	0	25	2
Total with parting -		-	27	2

In one shaft, however, the coal was found to be separated into two by a great cake of sandstone, 60 feet thick, the section being—

	FT.	IN.	FT.	IN.
Upper part of Thick coal -		-	19	6
Sandstone - - -	60	0	–	
Lower part of Thick coal -		-	4	6
			24	0
			84	0

The whole of the coal also, even where it was not separated by large beds of sandstone, was flecked, and veined with it in all directions, little seams of white sandstone, from a quarter of an inch to two or three inches in thickness, occurring here and there throughout the coal. In some places, too, in the gate-roads, a more considerable body of sandstone might be seen either interposed between two coals, or taking the place of one or other of them for a certain distance.

There was little or no mingling, or kneading together, of the two substances in the same mass, but merely a minute interposition of the two, the sandstone even in the thinnest layers being often clear white quartzose sand, while the coal was clear brilliant black, with apparently even less earthy admixture than usual. The deterioration in the commercial value of the coal was not its inferior quality as coal, but the difficulty of getting large coals free from these layers of sandstone,

and the expense that would be incurred in separating the two substances if that were attempted. (See *postea*, p. 50).

All the evidence then at present known goes rather against the value of the coals and ironstones to be found in the corner of the coal-field that lies south of Oldbury, and east of Rowley Regis and Halesowen, for although particular spots may possibly contain workable beds of coal, yet the hitting on those spots must always be a matter of chance, as there seems to be no indications in the general mass of the ground to lead up to them.

North of Oldbury I know of no important variation in the character of the Thick coal, either towards Tipton or Wednesbury, until we return to the district near Bilston, already described.

In the Thick coal worked beneath the Lower red sandstone, or Permian of West Bromwich, the thickness is described as only 27 feet or 28 feet; but it appears to be all solid coal, with none but the most insignificant partings.

Rock faults, swells, rolls, &c.—There are some remarkable peculiarities and irregularities of structure, which, although by no means peculiar to the Thick coal, but occurring now and then in all beds of coal in all coal-fields, are yet so well seen in the Thick coal on account of the scale on which they are exhibited, that it is worth while to take this opportunity of describing them a little more in detail.

One kind of irregularity has been just alluded to, namely, the occurrence of sandstones in the mass of the coal, or in the place of it. This is often spoken of by the miners, under the name of a "rock fault," a term we may use for want of a better, though it is apt to give rise to confusion, unless it be carefully distinguished from the true "fault," a dislocation which is quite independent of the character or quality of the beds.

Rock faults seem to be of two kinds, the one like that described by Mr. Buddle, under the name of "The Horse," as occurring in the Forest of Dean coal-field, which seems to be the result of a partial denudation or wearing away of the coal just subsequent to its formation, the hollow thus eroded being filled with whatever substance it was that was next deposited on the top of the coal. The other kind of rock fault arises from the contemporaneous deposition of sand or silt together with the coal, so that the formation of the two alternated at comparatively short intervals and over a comparatively small space, so that the whole coal incloses cakes, layers, or masses of sandstone of greater or less magnitude, and more or less intermingled with it. These masses may sometimes apparently be so large as over a certain part of the area to exclude the coal altogether, although they dove-tail into it, and are interlaced with it in interstratified layers round the margin of the area.

I never had the opportunity of personally examining an example of the first kind of rock fault. Mr. Aaron Peacock, however, described one to me as occurring a little west of Oldbury, in the Gower pits at the northern foot of the Rowley Hills. According to this description, which was very carefully given, there was a gap in the Thick coal 60 yards wide, and of much greater length. The bed on which the Thick coal rests is there called the "pouncill batt," and he described this as running under the Thick coal and across the gap the whole way with great regularity. The Thick coal was said to end on each side with a smooth slope, and the Broad earth or Cat earth above the coal was described as coming down over this slope, and running along *upon* the

pouncill batt till it met the other slope, when it rose over it on to the top of the coal again. The distance from the point where the Thick coal first began to diminish in thickness to that where it ceased altogether was about 80 yards, which would give a slope of about 7°. The Cat-heath (or earth) above the coal is about 5 feet thick in the neighbourhood, with sandstone over it, varying in thickness from 12 to 30 yards. In some places, however, there is no Cat-earth, and the sandstone rests directly on the coal. Over the above-mentioned gap in the Thick coal the sandstone is thicker than ordinary, and in one place it is 60 yards thick. The face of the slope of coal on each side of the gap was quite smooth, without any intermingling of the Cat-earth or sandstone with the coal. Unfortunately these workings were under water when the country was surveyed, so that it was impossible to verify this description, which I believe to be sufficiently accurate.

Of the second kind of rock fault I had fortunately a good opportunity of examining an example, through the kindness of Mr. George Thompson, who several times accompanied me through the under-ground workings, and gave me every information both there and in his office.

It occurs at the Baremoor colliery, about three miles south of Dudley. The Thick coal is worked all round the neighbourhood with its usual thickness and characters, and at a depth varying from 350 feet to 600 feet below the surface. A little above it is the usual Thick-coal rock or sandstone, rather thicker, perhaps, than it is generally found in other parts of the coal-field. The following section* from the Old Lion colliery, east of Baremoor, represents very closely the usual section found in all the pits about. (See Vertical Sections, sheet 18, No. 22.)

		FT.	IN.
1.	Upper measures	448	4
2.	Two-foot coal	2	3
3.	Batt and coal mixed	3	0
4.	Brooch coal	2	6
5.	Brooch-stone measures	4	10
6.	Herring coal	1	6
7.	Pins and pennyearth	17	2
8.	Cannel coal	0	9
9.	Brown clunch	3	6
10.	Thick-coal rock, composed of rock binds (argillaceous sandstone) and peldon (hard flinty stone)	106	2
11.	Cat-heath (catch-earth)	1	6
12.	Black batt	3	4
13.	Thick coal and partings	31	0
14.	Black batt	2	0
15.	Gubbin ironstone measures	10	6
16.	Heathen coal	3	5
17.	Parting	2	0
18.	Second Heathen coal	3	3
19.	Table batt†	0	10

* Communicated by Charles Small, ground bailiff, and given now instead of the Old Baremoor or Congreaves sections, which have been already published in Murchison's Silurian System.

† The batt, which generally goes by the name of the Table batt, is above the Heathen coal and underneath the Gubbin ironstone, and would lie between Nos. 15 and 16 of this section.

	FT.	IN.
20. White rock and peldon - - - -	15	9
21. White ironstone measures - - -	5	4
22. Cake ironstone measures - - -	3	0
	671	11

Now if with that section we contrast the following one, found in sinking the new Baremoor pit, we shall at once see the whole amount of the change :—

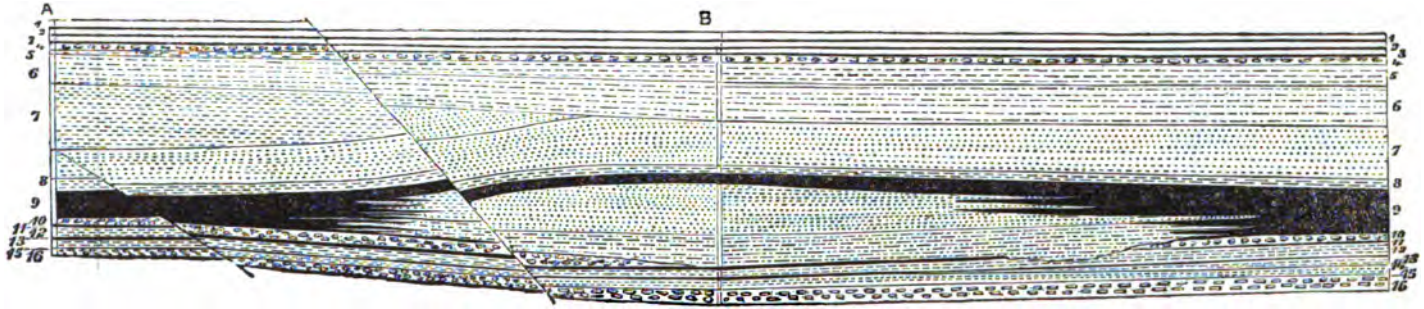
	FT.	IN.
*7. To the bottom of the Pins and Pennyearth -	280	4
8 & 9. Heath measures - - - -	15	0
10. Thick-coal rock, composed of rock binds and sandy rock - - - -	107	0
11. Cat heath - - - - -	2	0
12. Black batt - - - - -	3	0
13. Top part of thick coal - - -	9	0
Black batt - - - - -	0	8
Sandy rock, mixed with clunch - -	42	0
Rock binds - - - - -	44	8
15 ? Black batt - - - - -	0	4
16. Heathen coal - - - - -	2	10
17. Black batt and fire-clay - - -	5	10
17. Brown rock - - - - -	0	10
17. Black batt - - - - -	1	0
18. Second Heathen coal - - - -	3	2
19. Black batt - - - - -	1	4
20. Soft brown parting - - - -	0	3
20. Peldon and rock mixed - - -	4	0
20. Strong white ground - - - -	13	4
21. Whitestone measures - - - -	6	6
	533	1

Here we find that in this shaft all the measures were regular until they came down into the Thick coal, which, however, they passed through in about 9 feet, and came into sandstone. This 9-foot coal was then worked, and it was said to thin out in every direction by the gradual bending down of its roof, till it was no longer worth following. The shaft having been continued into the Whitestone measures without finding any more Thick coal, and the two Heathen coals having been found lying regularly below, they then proceeded to drive gate-roads (or galleries) from the surrounding excavations in the undiminished Thick coal towards this new Baremoor shaft. In so doing they discovered the nature of the mass of interposed sandstone ; and in the year 1849 they had already worked round three sides of it, and thus partially proved its extent.† They found it to be an oval cake of

* I begin with the same numbers as the last section, for the sake of easy reference.

† See Figure No. 5, a section on a true scale of the bottom part of the Baremore shaft, and the adjacent measures.

Fig. 5.



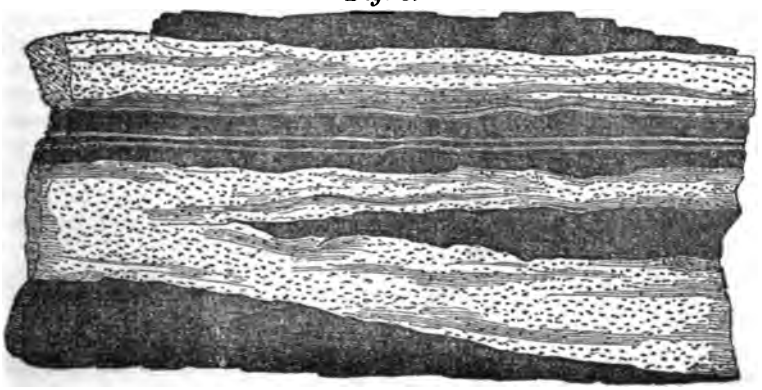
Scale, 1 inch = 133 feet.

A The Old Baremoor shaft.
B The New Baremoor shaft.
1. The Two-foot coal.
2. The Broach coal.
3. The Herring coal.
4. The Broach binds ironstones.
5. Heath measures.
6. Rock binds, argillaceous sandstone.
7. Rock, sandstone.
8. Cat-heath.
9. The Thick coal.
10. The Grains and Gubbin ironstone.
11. The first Heathen coal.
12. Black batt and fire-clay.
13. Second Heathen coal.
14. Batt and soft ground.
15. Rock, sandstone.
16. Cake and white ironstones.

sandstone, the major axis of which ran nearly due north and south. It was 13 chains or 286 yards wide, and it had been already traced north and south through a space of about 400 yards without reaching its northern extremity. In driving a gate-road towards it in the lowest part of the the Thick coal, it was found that at the height of about 10 feet from the bottom of "the benches," sandstone came in, and formed the roof of the coal; and from that point the sandstone gradually descended, and cut out bed after bed of coal until it reached the bottom of the benches, and some portion of it even descended below the Thick coal, and cut out the upper Heathen coal. When I first visited this gate-road, it was supposed that this sandstone had cut out the whole, not only of the lower part, but also of the upper part of the Thick coal; and the ground bailiff and colliers assured Mr. Thompson that they had bored upwards for several yards, and found nothing but "rock." This, on the subsequent extension of the workings, was proved to be merely one of those falsehoods that these men so frequently assert to save themselves a little trouble. In 1851 the upper part of the Thick coal was found to extend some distance over the extreme point of the interposed sandstone, and there is very little doubt that the 9-foot coal passed through in the New Baremoor shaft, instead of thinning out in every direction, really thickens gradually towards the upper part of the Thick coal around it. What makes this more probable is, that in working from the Thick coal around, towards the shaft, the coal became hard and intractable, making it more difficult to get. It is probable that for this reason the ground bailiff or butty collier, at that time in charge, declared it thinned out, and was not worth following.

This mass of interposed sandstone was very fine grained, rather soft, slightly argillaceous, of a light, greenish white colour; not at all differing from the usual argillaceous sandstones of the neighbourhood, which pass under the name of "rock" or "rock binds." It was not only interstratified with the coal *en masse*, but at or near the junction of the two they each split up into many beds, that interlaced with the utmost regularity. Beds of sandstone, two or three feet thick, extended many yards into the coal, gradually thinning out and splitting up, so that hand specimens could be procured of alternations of bright coal and pale sandstone, each little bed being not more than one tenth of an inch in thickness. Similarly did small beds and thin laminæ of coal stretch into the mass of the sandstone; a few separate masses also, a foot or so in thickness, sometimes occurring suddenly, not as detached fragments, but as little independent beds in the sandstone. Of the alternation and interstratification of the two materials the following cut (Fig. 6) will give a good idea:—

Fig. 6.



D

This figure is taken from a hand specimen, and is three-fourths the natural size. If it were supposed to be indefinitely enlarged till each bed of coal was 2 or 3 feet in thickness, it would do equally well for a representation of the interlacing of the larger beds. It must be borne in mind that even the minute seams of coal in the above-drawn hand specimen were not mere carbonaceous matter, but were perfectly bright, good coal; and that little or no difference was perceived in the quality of the coal interstratified with the rock fault, and that of the same beds in the unaffected coal around it.

It is clear from the above facts that this is not a case of any kind of denudation of the coal subsequently to its formation, but that whatever cause produced this mass of interposed sandstone was acting *during* the time of the formation of the coal. We will, however, defer the consideration of the theoretical inference to be deduced from these cases to a future page.

The occurrence of the "rock and rig" or white sandstone, more or less streaked with coal in the Thick coal at Dr. Percy's pits and the neighbourhood, about a mile to the south-east of Tividale, is one of precisely similar kind to that just described. Great irregularly formed beds of this sandstone come in, over, under, and among the coals there, the coal being sometimes streaked and veined with sandstone layers, and the sandstone having often vein-like layers of perfectly bright coal. In some places there the coal seems to have been partially eroded, and patches of black batt covered by sandstone deposited in the hollows thus formed, in others the two substances were evidently deposited in alternate layers of an inch or two in thickness, the layers of each substance thickening out and coalescing in opposite directions into larger and larger masses.

The whole measures, however, here have been evidently subject to great squeezing and dislocation. They are traversed by faults, and slickenside surfaces are seen in every direction, and sometimes the layers, especially those of coal lying in the sandstone have been bent, and are now tortuous like veins, while masses of the sandstone have likewise indented the coal.

The confusion is further complicated by veins of trap, which are all of a white colour, having intruded into both coal and sandstone, as will be described further on.

Mr. Cooksey, who accompanied me over these workings during the past year (1858), informed me that in driving gate-roads through these masses of intertangled coal, sandstone, and trap, they had met with one or two cakes of unaltered and uninjured Thick coal, of sufficient extent to pay part of the unprofitable outlay in making explorations.*

I also, in October 1858, visited the under-ground workings of Messrs. Harper and Moore's colliery at Causeway Green, accompanied by their agent, Mr. Green. The great cake of sandstone, 60 feet thick, spoken of at p. 44, must undoubtedly be an example of a rock fault. We were not then able to examine it, but in some of the gate-roads I observed masses of sandstone lying in the coal, in so remarkable a manner that I made sketches and measured them as accurately as could be done under ground without greater preparation. These are shown in Figs. 7 and 8.

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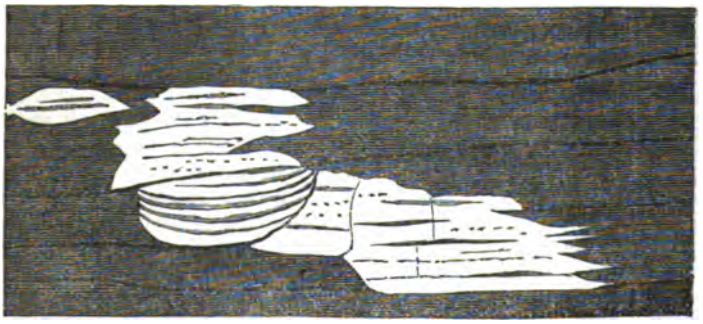
* I have been since informed (July 1859) that they have now driven beyond all this "troubled ground" into good uninjured Thick coal without either sandstone or "white rock" trap.

Fig. 7.

Scale, 8 feet to 1 inch.

The mass of sandstone shown in Fig. 7 was about 18 feet long and 5 or 6 feet high. It was of a pale greenish grey colour, fine grained, principally quartzose, with a little argillaceous matter mingled with it. It occupied parts of four beds of coal, but although laminated throughout and marked here and there with dark carbonaceous streaks, or even little seams of bright coal, it did not seem itself to be separable into four beds, nor was there any distinct plane of stratification (distinct from the lamination) visible in it. Its form was as nearly as possible that given in the sketch, the indentations being as sharp and angular as there drawn. The thinning and arching of the coal over the thickest part of the sandstone was very noticeable.

Fig. 8.



Scale, 4 feet to 1 inch.

Fig. 8 is a similar sketch, taken in a neighbouring part of the same gate-road, drawn on twice the scale. The principal mass of sandstone was about six feet long, with a smaller mass of two feet at one corner. The sandstone extended through three beds of coal, but was more separated by rather irregular planes of stratification than that seen in Fig. 7.

Many other masses of pale sandstone were to be seen in the coal on each side of these gate-roads, while in some places the whole coal seemed mottled and streaked with flakes of sandstones. It was especially remarkable that the thin seams of coal interstratified with these sandstones, seemed even brighter and purer than the main mass of the coal, where it was without any interlacing of arenaceous layers or masses.

Rolls, Swells, &c.—The second peculiarity of structure in the Thick coal is that which forms those irregularities, called "horse's backs," "rolls," "swells," "pack-saddle faults," &c. These are caused by a rise of the floor of a coal up towards the roof, in such a manner as to form a long arched ridge running through the coal, sometimes for a very considerable distance. I examined one of these in the Baremoor colliery, when visiting

1
2
3
4
a
b
b
a
Scale, 16 feet to 1 inch.
a Bottom part of Thick coal. 1. Patchells. 2. Sawyer. 3. Slipper. 4. Benches.
b Swell, or horse's back, consisting of dark clunch (black clod). c. Large irregular nodules of ironstone.

Fig. 9.—Section of a "swell" in the Baremoor colliery.

it with Mr. Thompson. The black batt containing nodules of ironstone, which usually lies below the coal, seemed to thicken upwards very gradually, and the three lower coals ended against it with a distinctly rounded outline, and without any mark or sign of disturbance, either contemporary or at a subsequent period. So gradual was the rise of the lower batt, that at one part of the gate-road it required 18 feet of horizontal distance to rise 2 feet 9 inches vertically. In other words, the slope was not so much as 1 in 6 (=9°).

Fig. 9 is a sketch of the transverse section of the swell, from a rough drawing and measurement on the spot.

After continuing for a few feet in the Patchells, the crest of the swell gradually descended, letting in the lower coals again, the two sides of it being nearly, if not quite, symmetrical. I do not know what was the longitudinal extension of this particular ridge, but they are often met with one or two hundred yards long; and sometimes one or two will run close together, parallel to each other, for that distance.

It is, of course, possible that they might in some cases have been caused by disturbance anterior to or contemporary with the formation of the lower part of Thick coal, though, in that case, the beds below would be equally bent, which is not, I believe, found to be the fact. It is, however, much more likely that they were merely long ridge-like accumulations of mud or sand piled up in the water in which the measure forming the floor of the coal was deposited. Theoretically, they are important as showing that whatever was the process of the formation of coal, it was in this case necessarily formed in a strictly horizontal position. The lowest bed of the Thick coal (see Figure No. 9) ended against the very gentle slope of the swell, and no bed was formed over it until a sufficient accumulation of coal had taken place around it to make a floor level with its crest. The minute partings of shale or earth between the different beds of coal in the Baremoor colliery sensibly thickened as they approached the swell and coalesced with it.

In a practical point of view these swells are worthy of study, inasmuch as they often diminish or destroy the value of a tract of coal. They very frequently occur, I believe, in all coal-fields, but it is not always that they can be so well examined and understood as in the Thick coal of Staffordshire. They are commonly spoken of by the colliers as faults, a term likely to lead all concerned into great

errors, and which, in a case within my own experience, was the origin of a dispute between two gentlemen in South Staffordshire, involving considerable legal expenses.*

13. (*I.* 4.) ***Pouncill batt, Blacktry and Whitery, containing the "Grains" ironstone, and sometimes the "Whitery" ironstone.***—Immediately under the Thick coal is almost invariably a bed 1 or 2 feet thick of "black batt," dark bituminous shale, which, in the districts immediately east and west of Dudley is called the "Pouncill batt." Under that is from 1 to 3 or 4 feet of dark "ground" or clunch, called "Blacktry." This in the central and southern parts of the fields often contains small nodules of ironstone, called the "Grains ironstone." Under that is 1 or 2 or 3 feet of a light coloured ground or clunch, containing also in some cases ironstone called the "Whitery ironstone." The three beds together never exceed 8 feet in thickness; they are rarely all present at once, the batt seeming the most constant, but they are sometimes altogether wanting, and the Thick coal rests on the measures containing the Gubbin ironstone. In one instance, namely, at Tipton Green, their place is taken by 6 feet of grey rock.

In the Bentley district there is a little coal and ironstone, which, from its position above the top Gubbin, seems to belong to these beds. The following is a section supplied by Mr. James George :—

	FT.	IN.
Ironstone - - - -	0	2
Clunch - - - -	0	10
Batt - - - -	0	5
Ironstone - - - -	0	2
Coal - - - -	1	2
Clunch - - - -	3	0
Clunch and ironstone - -	4	0
	9	9

These measures are there known by the name of the "Bind coal and ironstone."

14. (*I.* 5.) ***The Gubbin or Little Gubbin ironstone.***—This seems to be one of the most constant beds in the whole district. It generally contains ironstone of good quality, and has been greatly worked. The measures usually consist of dark clunch, containing isolated ironstone nodules in one, two, or three bands. Between Bilston and Wolverhampton the measures are from 2 to 4 feet thick, but around Dudley they are generally 6 feet, and sometimes 7, 8, or 9. The following detailed section occurs at Upper Gornal clay-works,† and will give a good idea of the structure of these measures :—

	FT.	IN.	FT.	IN.
Ironstone - - -		-	0	6
Dark clunch - -	2	0	–	
Ironstone (cannock) - -		-	0	6
Dark clunch - -	2	0	–	
Ironstone (rubble) - -		-	0	3
Black batt - -	0	6	–	
	4	6	1	3
Total, with partings - -			5	9

* The theoretical and practical importance of these "swells" will be further noticed hereafter (see pp. 190 and 191.)

† Communicated by Mr. Kenyon Blackwell, to whom I must return thanks for much valuable information.

In some parts around Dudley the ironstone of these measures is called "Blackstone," to distinguish it from the "Whitestone," hereafter to be described.

About Bentley this Gubbin ironstone has a little coal associated with it, as in the following section:—

	FT.	IN.
Binds	1	0
Ironstone (Gubbin)	0	6
Binds and batt	1	3
Coal and batt	1	2
Fire-clay	0	10
Coal	0	7
Binds	21	0
Clunch and ironstone	3	0
Black batt	0	11
	29	3

Comparing this section with the one given below from Claycross, it seems probable that the Black batt 11 inches which rests directly on the Heathen coal, is in reality the Table batt, which at Claycross also reposes directly on the Heathen coal.

15. *Table batt and intermediate measures.*—The Table batt is a very compact, black, carbonaceous shale, splitting into large slabs, which when first exposed look firm, but soon crumble to pieces. It is found throughout the southern district with a thickness varying from 2 to 4 feet, except in the neighbourhood of Congreaves, and thence towards Stourbridge and Kingswinford, where I find no mention made of it, and around Corbyns Hall it is only 1 foot thick. Sometimes it has associated with it a little coal and ironstone, as in the section at Claycross, near Dudley, which will be useful for comparison with sections farther north:—

	FT.	IN.
Sharp batt	1	6
Rubble stone	0	5
Little coal	0	6
Brown stone	0	5
Table batt	2	6
	5	4

The measures between the Table batt and the Heathen coal are wholly confined to the district between Walsall and Wolverhampton. We have seen that in the south-western angle of the coal-field the last measure is wanting, and there the Gubbin ironstone measures rest directly on the Heathen coal. Proceeding in every direction from this part, the Table batt comes in between them, at first only a few inches thick, but gradually swelling to 4 feet. Still, in the district around Dudley there is nothing else to be found between the Gubbin and the Heathen coal; but, as we approach Bradley, we get eventually about 10 feet of fire-clay and clunch, and farther north we find a pretty regular thickness of from 18 to 24 feet (or 6 to 8 yards) of clunch, binds, or other argillaceous material, commonly of a white colour, interposed between the black table batt and the heathen coal. Sometimes a "black ring,"* or a small coal 6 or 8 inches thick, makes its appearance

* A "black ring" when mentioned in a pit section means an impure coaly bed, sometimes called "smut," &c.; it forms a black ring round the shaft, whence its name.

in the upper part of these measures, and in the lower part of them there are sometimes ironstone nodules, which are called either Lambstone* or Heathen coal stone.

16, 17, 18. (XVI.) HEATHEN COAL,† *intermediate measures and* (XVII.) RUBBLE COAL.—I take these two coals and their intermediate beds together, because I believe that the Rubble coal of the northern part of the district is the second or Lower Heathen of the southern part.

The Heathen or Upper Heathen coal is a very well marked bed over nearly the whole of the coal-field; it varies from 1½ to 4 feet in thickness; its usual thickness being about 3 feet. Even as far north as the Brown Hills, in the deep pit of the Cathedral colliery, there is a coal which is called Heathen coal, and I believe rightly so called. It has there a thickness of 2 feet 6 inches.

In the district around Congreaves, Cradley, and south of Brierly Hill, there is always mentioned a second or Lower Heathen coal, about 2 feet thick, and from 10 to 20 feet below the first or upper Heathen coal. The beds between the two thicken to the south, and at Mr. King's pits at Netherend are 43 feet thick, chiefly sandstones: they thin out to the north, and about Corbyns Hall, Shut End, and Kingswinford they first of all thin to 1 foot, and then disappear altogether, the two Heathen coals then being considered one coal, and having a thickness of from 5 to 7 feet. Just on either side of Dudley there appears to be neither Lower Heathen nor Rubble coal, but from Tipton northwards around Bilston and thence to Wolverhampton, there is almost always a Rubble coal varying in thickness from 2 to 4 feet, and in depth below the Heathen, from 7 to 24 feet. The interposed materials contain always clunch and other argillaceous matters, and often some sandstone, which occasionally thickens out, and causes the variations in thickness between the two coals. I believe, therefore, that what is called Rubble coal in the district north of Dudley is the same bed with the Lower Heathen coal of the district south-west of Dudley. There is, however, no mention of any Rubble coal beneath the Heathen in the Deepfields sections, nor does it appear to exist in the Bentley district.

19. (*I.* 6.) *Measures between the Heathen and Rubble coals and the New mine ironstone, containing at Bentley the ironstones known there as the Lambstone and Brownstone.*—These beds, in the great majority of instances, wherever they are known, are composed of rock, peldon, and rock binds; that is to say, some variety of sandstone. Sometimes, however, they are said to consist more or less of binds, clunch, or clod, and in a few instances to be entirely composed of those argillaceous materials. Their thickness varies from 10 feet to upwards of 30 feet, the average and by far the most usual thickness being between 15 feet and 20 feet. In some cases, as at Baremoor in the Congreaves district, they contain ironstone, there called "Ballstone," as also at Coseley, Gornal, and in the Chillington field, in which latter place there are two courses of ironstone called "Bindstone."

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* "Lambstone," I am inclined to suppose to be a corruption of "loam stone;" or it is perhaps another form of the same word, and ought to be written "lam."

† This is now the customary orthography of this word in the district. I have, however, seen it written "eathen." The presence or absence of the aspirate is of no account in the matter, as most of the colliers would speak of "a hegg." I believe, therefore, that this term is a corruption of "earthen" as in the case of the "broad heath," &c., mentioned before. Probably the coal when it was first got had an earthy quality or appearance. Mr. Keir, however, writes it "heathing" coal, and it may very well be derived from some obsolete word with which I am not acquainted.

At Bentley the beds next below the Heathen coal are as follows:—

	FT.	IN.
Clunch - - - -	0	10
Clunch and ironstone - -	9	0
Ironstone (Lambstone) - -	0	3
Clunch - - - -	2	6
Black batt - - -	1	0
Ironstone (Brownstone) - -	0	6
Clunch, ironstone, and black batt -	3	3
Other measures, with some ironstones - - -	14	10
New Mine ironstone - -	1	6
	33	8

The ironstone called Brownstone resembles the Black band of Scotland, and is the only ironstone of that quality known in the South Staffordshire coal-field. The Lambstone and Brownstone are not known south of the Great Bentley fault, neither do they range very far to the north of it.

20. (*I.* 7.) *New mine ironstone, or White ironstone.*—This is perhaps the most widely-diffused bed of ironstone in the whole district, as it occurs and is worked from Bentley near Walsall on the north to Hawne near Halesowen on the south. The measures consist almost invariably of clunch, though sometimes they are called clod, or binds; they are always, therefore, of some form of clay; they contain from two to four bands or courses of ironstone, each of which varies from an inch to a foot in thickness. The whole measure is generally 4 feet or 5 feet in thickness, sometimes as little as 2 feet, sometimes, but very rarely, as much as 10 feet.

The following are some details of this measure from different parts of the field:—

Northern part of Bentley estate.

	FT.	IN.	FT.	IN.
Ironstone - -	-		0	3
Clunch - -	0	7	–	
Ironstone - -	-		0	4
Clunch - -	3	3	–	
Ironstone - -	-		0	4
	3	10	0	11
Total with clunch -			4	9

Chillington, near Wolverhampton.

	FT.	IN.	FT.	IN.
Top ironstone -	-		0	3
Clunch - -	3	3	–	
Bottom ironstone	-		1	6
	3	3	1	9
Total with clunch -			5	0

Highfields, near Bilston.

	FT.	IN.	FT.	IN.
Ironstone - -	-		0	3
Clunch - -	1	10	–	
Ironstone - -	-		0	3
Clunch - -	1	10	–	
Ironstone - -	-		0	6
	3	8	1	0
Total with clunch -			4	8

Foxyards, near Dudley.

	FT.	IN.	FT.	IN.
Ironstone - -	-		0	5
Clunch - -	1	6	–	
Ironstone - -	-		0	1
Clunch - -	1	3	–	
Ironstone - -	-		0	3
	2	9	0	4
Total with clunch -			3	6

Gornal Clayworks.

	FT.	IN.	FT.	IN.
White clunch -	1	6	–	
Ironstone - -	-		0	3
White clunch -	2	0	–	
Dark clunch -	1	0	–	
Ironstone - -	-		0	3
	4	6	0	6
Total with clunch -			5	0

Corbyns Hall.

	FT.	IN.	FT.	IN.
Top ironstone -	-		0	9
Clunch - -	5	6	–	
Bottom stone -	-		1	0
	5	6	1	0
Total with clunch -			7	3

Dudley Woodside.

	FT.	IN.	FT.	IN.
Ironstone - -	-		0	$2\frac{1}{2}$
Clunch, &c. -	4	0	–	
Ironstone - -	-		0	$3\frac{1}{2}$
	4	0	0	6
Total with clunch -			4	6

Around Dudley and to the south-west of it, as also east as far as Oldbury, on the one side, and north to Ettingshall-lane on the other, the most usual name for this measure is White ironstone. Within these limits it is almost the lowest bed from which ironstone is gotten, and is that on which of late years the principal dependence has been placed. To the north-west, around Wednesbury and Bilston, and between Wolverhampton and Walsall, this measure is invariably called New mine stone, and in that district it is one of the uppermost ironstone measures, much richer and more important beds being there found below it.

21. (*I.* 8.) *Intermediate measures containing the Pennystone ironstone, called also the Bluestone and the Cakes.*—These beds are almost invariably dark clunch. They are called sometimes black clod and black ground. They contain sometimes throughout their mass, sometimes only in the lower portion of it, flat roundish nodules of ironstone, generally of a dark colour, and sometimes black, so as to be distinguishable from the New mine Whitestone above them, both in form and colour. The ironstone is sometimes called Blue ironstone, or the Cake ironstone,* as well as Pennystone. South and west of Dudley they rarely contain ironstone, and the whole mass scarcely ever exceeds 5 feet in thickness, being frequently altogether absent, the only exception I know being at the Graveyards near Lower Gornal, where they are described as "Pennystone measure, 18 feet." In the centre of the field between Dudley and Wednesbury ironstone is likewise often absent, as at Tipton Moat colliery, where we have only "dark ground 20 feet." South of that, however, towards Oldbury, ironstone is got from these beds under the name of Cakes or Bluestone; and northwards between Wolverhampton and Walsall, the Pennystone measures are mentioned in nearly all the sections, with a variable thickness of from 10 to 25 feet, sometimes generally, as occupying all the space

* There is a Cake ironstone worked immediately under the Whitestone at the pits round Cradley Heath, &c., which is probably the same as the Cakes east of Dudley.

between the New mine stone and Sulphur coals, sometimes, as at Ettingshall Lodge colliery, in the following form :—

	FT.	IN.
New mine stone, in two measures	3	3
Dark clunch - - -	9	0
Pennystone measures - -	6	0
Sulphur coal - - -	2	6

To the palæontologist it will be interesting to know that* marine shells in considerable abundance occur near Oldbury in the lower part of the New mine stone and the upper part of the Pennystone, like those so well known in the neighbouring coal-field of Shropshire. They are, however, confined to a very small district between Oldbury and Portway. In one mass of ironstone *Lingulæ* were mingled with the common shells called *Unio*,† which are so abundant in many of the ironstones; but it appeared that generally where undoubtedly marine shells were present these so-called *Uniones* were absent. *Lingulæ* are also found in other parts of the coal-field and in lower measures. The *Producta* was observed by me in 1858 as occurring also in considerable abundance in the "White" ironstone between Rowley Regis and High Haden.

22. (XIX.) Sulphur Coal.—This is called as frequently the Stinking coal. It is, I believe, rarely used, on account of its impure and sulphureous qualities. It is, however, mentioned in its proper place in nearly every section we have over the whole district from Hawne, where, with a batt, it is 2 ft. 6 in. thick, up to Bentley and the Brown Hills, where it is generally stated as from 1 foot to 4 feet in thickness. At Coneygree near Dudley it is said to be 6 feet thick; and at Tipton-green the Stinking coal and batt is described as having a thickness of 9 feet. Generally its thickness varies from 2 feet to 4 feet, except around Corbyn Hall and Shut End, where it is often only 2 or 3 inches thick.

At the Cathedral pits in the Rising Sun trough at the Brown Hills, the Sulphur or Stinking coal occurs at a depth of 250 feet, a depth which should bring in the Heathen coal and Thick coal, if the beds in the northern part of the field retained the same structure which they have in the south. The following is an abstract of the section there :—

		FT.	IN.	FT.	IN.
1.	Soil, and clay, sand and gravel -	45	6	81	0
2.	Black and grey clunch - -	35	6		
3.	Coal, believed to be the Bentley Hey coal		-	3	10

* My late lamented colleague, Professor Edward Forbes, informed me that these fossils are :—

Producta scabricula.
Avicula quadrata.
Pecten (?) unnamed.
Lingula mytiloides (?).
Orbicula nitida.
Conularia quadrisulcata.
Fish teeth and *bones* undetermined.
An *echinus* very much broken up, probably *archæocidaris*, but in too fragmentary a state to be exactly determined.

† Now known as *Anthracosia.*

		FT.	IN.	FT.	IN.
4.	Fire-clay, with small brown ironstone	7	0		
5.	Dark shales and ironstone	2	5	33	8
6.	Dark shales	24	3		
7.	Coal*			1	1
8.	Shale, binds, and rock binds	24	10		
9.	Shale, with ironstone†	2	3	27	1
10.	Coal of bad quality†			0	6
11.	Bastard fire-clay, with ironstone balls†	9	0		
12.	Dark shales and white rock	29	4	38	4
13.	Coal (Heathen)			2	6
14.	Fire-clay and shale	4	6		
15.	Dark shale, with nodules of ironstone‡	6	6		
16.	Ditto, with clay ironstone and brown ironstone‡	2	10		
17.	Light coloured fire-clay, shale and rock binds	24	0	62	0
18.	Dark shale, with measure of ironstone§	16	6		
19.	Dark shale	7	8		
20.	Coal (Sulphur or Stinking)			1	8
				251	8‖

The next coal there below this Stinking coal is a coal which we shall afterwards prove to be the top of the New Mine.

There can be little doubt that the beds containing ironstone which come above this Sulphur coal are the representatives of those just described as the Pennystones and New Mine ironstones, and that the coal No. 13 is the true Heathen coal; while the beds numbered 9, 10, and 11 are probably the little Gubbin ironstone and coal, as it makes its appearance at Bentley; and coal No. 7 is the Bind coal which comes in at Bentley with the same thickness, but associated with ironstone.

23. *Beds between the Sulphur and New mine coals.*—In the Priestfield colliery between Bilston and Wolverhampton there is in one pit 99 feet of binds and rock in this position, and in all the adjoining collieries there are 70 feet or 80 feet of the same materials, the sandstone predominating and passing under the name of the New-mine-coal rock, or the Twenty-yard rock. This mass of rock is variably split up with rock-binds and peldon, sometimes with clunch. There is often above it a bed of fire-clay or of clunch a few feet in thickness, supporting the Sulphur coal, but that is frequently absent, and that coal rests directly on the sandstone. Going north towards Bentley the thickness of these measures diminishes to about 30 feet or 40 feet. Going south from Bilston they are still 70 feet at Highfields, consisting of rock and peldon; but at Deepfields there is only 5 feet of fire-clay and 40 of binds, and at Tipton Green but 15 feet of rock, which at Foxyards

* Probably the Binds coal of Bentley.
† Probably the Little Gubbin coal and ironstone.
‡ Probably the New Mine stone.
§ Probably the Pennystone.
‖ For the whole of this section, see Vertical Sections, sheet 26, No. 41.

seems to altogether die out, and 2½ feet of fire-clay alone to interpose between the Sulphur coal and those below it. These great variations in thickness seem to take place principally in the sandstone, which, for instance, about Coseley is only 15 feet thick, while it is more than 60 feet not half a mile off. North of Darlaston, between the Ranters' chapel and Darlaston Forge, the New mine rock, having gradually thinned out from Bilston to a thickness of 9 feet only, suddenly swells out to 78 feet with such rapidity that it was described to me at first as a "fault," by which the Heathen coal and upper measures were thrown up 60 feet or 70 feet.*

The sandstone known as the New-mine-coal rock extends even as far as the Brown Hills where it is known as the Yard-coal rock, the Yard coal being the upper and separated part of the New mine. The rock is there 30 feet thick.

24. (XX.) NEW MINE COAL.—This coal has its normal development in the district between Wolverhampton and Bilston, where it is very regular, and is always 6 or 7 feet in thickness. It is split into two, occasionally, by a thin parting of batt of some 6 or 8 inches. This parting is a little more pronounced at Monmore colliery, north of Willenhall,† where we have the following section :—

	FT.	IN.	FT.	IN.
Coal	-	-	3	9
Batt	1	2	-	-
Coal	-	-	4	6
	1	2	8	3

and about a mile north-east of that, around Bentley, the New mine coal is divided into two by measures which vary from 30 to 50 feet in thickness, composed partly of clay, but principally of sandstone.

These two coals there lose their name of the New mine, and are called respectively the "Yard coal" and the "Five-foot coal," or in some cases the "Four-foot coal," as shown in the following sections :—

Bentley Heath.

	FT.	IN.	FT.	IN.
Yard coal	-	-	3	3
Fire-clay	1	5	-	-
Rock	0	8	-	-
Clunch	3	0	-	-
Rock	35	6	-	-
Five-foot coal	-	-	5	0
	40	7	8	3

Birch Hills Colliery.

	FT.	IN.	FT.	IN.
Yard coal	-	-	3	0
Fire-clay	6	0	-	-
White rock	12	0	-	-
Peldon	6	0	-	-
Rock binds	22	6	-	-
Four-foot coal	-	-	4	0
	46	6	7	0

* I shall hereafter have occasion to remark on the very vague way in which the term "fault" is used in this district, and the patient and skilful cross-examination often necessary to get at its true meaning in the mouth of a collier.

† In this colliery and the neighbourhood is so remarkable an instance of the phenomenon well known to all geologists as "false bedding," or "oblique lamination," that it is worth while describing it. Several small quarries had been opened in some light-coloured sandstone just above the New mine coal, the same as that just spoken of as the Twenty-yard or New-mine-coal rock, and over a space of nearly a quarter of a mile square, the apparent dip of that sandstone was seen in each quarry to be about 25° to the south-east. The sandstone was fine-grained, with *shaly partings*, often

Still farther north, about the Brown Hills, we have the following section :—

	FT.	FT.
Yard coal - - - -	-	- 3
Fire-clay - - -	- 5	—
Rock - - - -	- 40	—
Bass coal - - - -	-	- 6
	45	9

In this part, though only removed a very few miles from the Willenhall and Bentley district, the terms New mine, &c. are entirely unknown, and the identity of the Yard coal and Bass coal with the New mine quite unsuspected* (see Vertical Sections, sheet 26, Nos. 41, 42, 43, and 46).

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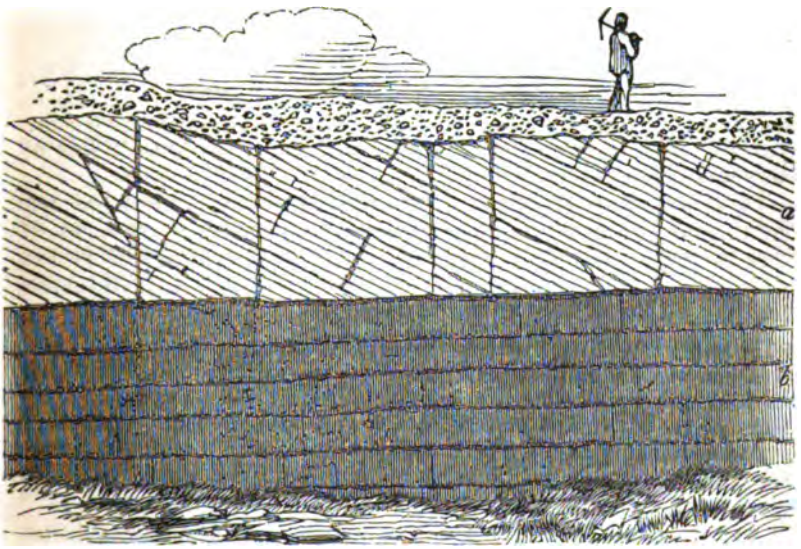
splitting into flags, and the whole of the lines representing stratification inclined at the same amount and in the same direction. As I knew the coal was worked at a very slight depth over all that space, I could not understand why it did not crop to the surface, till I came on a larger quarry that explained the puzzle. In this quarry the coal was seen lying as nearly horizontal as possible, with the shaly and flaggy sandstone dipping regularly down on to it at an angle of 25°.—(See Figure 10.)

Fig. 10.



a Fine-grained flaggy sandstone. *b* New mine coal.

There was no appearance of any lenticular thickening or thinning of the beds of sandstone, they simply ended against the upper surfaces of the coal, which, when bared, was found to be quite smooth, almost as if polished, but not quite level, forming slight undulations, but with no admixture of any other materials than coal. There were, in some places, about 15 feet of sandstone exposed, and about 8 of coal, the length of the quarry being about 50 yards, throughout which there was no material change in this structure. Like other similar structures in most sandy beds, it shows that the materials must have been brought into their present situation by a pretty rapid current, and that a bank being once produced, the successive accumulations were formed on the slope of it into inclined layers or beds.

* The real fact is, that the colliers of each small district neither know anything, nor care to know anything beyond the bounds of their own small locality, and those of Willenhall and the Brown Hills are thus reciprocally ignorant of each other's terms.

It is remarkable that in these and in most other cases of which I have the details, the two coals, though so widely separated, preserve the aggregate thickness of 6 or 7 feet, sometimes increasing to 8 or 9.

If we proceed from Bilston towards the south, we find that between Bilston and Tipton the New mine coal is either divided and increased, or other small coals come in just below it, and are naturally classed with it; for instance, we have the following sections:—

Bilston Meadow.

	FT.	IN.	FT.	IN.
Coal	-	-	5	0
Parting	1	3		–
Coal	-	-	4	4
Parting	0	4		–
Coal	-	-	4	4
	1	7	11	4
Total with partings			12	11

Highfields.

	FT.	IN.	FT.	IN.
Coal	-	-	6	0
Parting	2	10		
Coal	-	-	5	0
	2	10	11	0
Total with partings			13	10

Lower Bradley.

	FT.	IN.	FT.	IN.
Coal	-	-	5	5
Parting	2	1		–
Coal	-	-	2	0
Parting	0	6		–
Coal	-	-	3	0
	2	7	10	5
Total with partings			13	0

Still further south, however, at Tipton Moat colliery, the New mine coal is only 5 ft. 6 in.; at Tipton Green, 6 ft. 6 in., with a parting; and at Coneygree, near Dudley, 6 ft.

Going thence north-west to the Fox-yards, this coal thins to 4 ft.; and at Upper Gornal clay-works it is only 2 ft. thick.

Similarly to the east, it is only 1 ft. 6 in. at Messrs. Houghton's Whimsey colliery, near Oldbury.

In a cutting of the South Staffordshire Railway, near the Dudley "Castle foot pottery," the New mine and lower coals were distinctly seen cropping out to the surface, with a thickness of several feet, as also in the cutting on the Oxford, Worcester, and Wolverhampton Railway, on the south-west side of Dudley.

Proceeding farther towards the south-west, they appear rapidly to thin out, and finally disappear. A few deep sinkings have been made in this south-western district, in some of which, coals answering, perhaps, to the New mine and those below it, have been passed through, but in so debased a form that it is doubtful whether they are really the same beds, or other little coals occurring here and there near their place.

At the "Graveyard" trial pits, for instance, south of Lower Gornal, below the Sulphur coal, measures were found 22 feet 6 inches thick, consisting partly of clunch and fire-clay, but containing 15 feet of rock; and below them was a coal 1 foot 10 inches thick, believed to be the New mine.

At Upper Gornal clay-works there are 19 feet of measures, containing 7 feet of rock between the Sulphur coal, and the 2 feet of coal which represents the New mine.

Near Corbyns Hall, in three shafts, there was a coal 1 or 2 feet thick, which was from 45 to 60 feet below the Sulphur coal; the intermediate measures having several beds of rock, amounting altogether to upwards of 20 feet.

At Shut End the beds below the Sulphur coal are almost all fire-clay, but 10 or 12 feet of it is described as *gritty*, and at a depth varying from 15 to 30 feet is a small coal 1 foot 6 inches thick.

At the Oak Farm colliery there is a coal 1 foot 6 inches thick, 39 feet below the White stone measures.

At a deep sinking of Mr. Benjamin Gibbons's, at the Level colliery north-east of Brierley Hill, there were found below the Sulphur coal 35 feet of measures, of which 16 were rock; and below these was a small coal 1½ foot thick, which likewise may represent the New mine coal.

At the Ley's iron-works, north-west of Brierley Hill, Mr. Firmstone sank 280 feet below the Thick coal. Below what is probably the Sulphur coal he met with 22 feet of measures, containing 11 feet of rock, when he came on a "rubble" coal 1 foot 2 inches thick, which may perhaps be the New mine.

South of these two places no deep trials were ever made, except in the instance of the Blackheath colliery, south of Rowley Regis; and there nothing was found that could be at all supposed to represent the New mine coal, or any of the beds below it. (See Vertical sections, sheet 17 and 18.)

25. (*I.* 9.) ***Measures between the New mine and Fire-clay coals, containing occasionally the Fire-clay Balls ironstone.***—There is scarcely any group of beds in the whole coal-field which exhibits such rapid and strongly-marked variations as this group. Even in the limited district of the Stow Heath and Priestfield collieries, between Wolverhampton and Bilston, these beds vary from 2 or 3 feet of "binds" to 39 feet of "rock," with a little fire-clay above and below it (Vertical Sections, sheet 16, No. 10). Over the whole district in which the two coals occur, the changes in the beds between them are equally marked, even in closely adjacent localities.*

For instance, at the Chillington colliery they contain only batt and fire-clay, 4 to 9 feet thick; while a mile south of it, at Cockshutts, the beds are—

	FT.	IN.
Clod - - -	5	0
Rock - - -	26	7
Fire-clay - -	3	0
	34	7

At Ettingshall Lodge colliery they have—

	FT.	IN.
Batty fire-clay - -	5	9
Rock and rock-binds -	18	6
Dark clunch - -	3	7
	27	10

While at Ettingshall Lane colliery, one mile south, there are only 2 feet of fire-clay.

* Mr. Lionel Brough, Inspector of Collieries, informs me that at Rose Hill colliery there was only 6 inches between the New Mine and Fireclay coals, the space being occupied by the Fireclay Balls ironstone.

In the central part of the field, south of Bilston, we get the following sections :—

Bradley Lodge.

	FT.	IN.
Fire-clay and batt	4	8
Dark ground	3	0
Fire-clay and ironstone balls	3	9
	11	5

Lower Bradley.

	FT.	IN.
Fire-clay	9	8
Little coal	0	10
Fire-clay	6	0
Rock	3	0
Fire-clay balls, an occasional ironstone	3	0
Dark ground	4	0
	26	6

Around* Highfields, Deepfields, and Tipton colleries there are only 2 to 4 feet of fire-clay, clunch, or binds ; but at Coneygree, near Dudley, these beds again swell out to the following section :—

	FT.	IN.
Fire-clay	2	0
Rock-binds	8	0
Rough rock	3	6
Binds mixed with peldon	4	0
Fire-clay balls ironstone	4	0
Hard rock	3	6
Batt	1	2
	26	2

We will leave the attempt to trace these beds south and west of Dudley till after the description of the Fire-clay coal. Going north from the district already described, (north of Willenhall that is,) we find these beds to have a more constant character than elsewhere, always preserving a thickness of more than 20 feet, and consisting of alternations of rock, fire-clay, and clunch, as the three following sections will show:—

Central Part of Bentley Estate.

	FT.	IN.
Batt, fire-clay, and binds	8	8
Rock	1	4
Binds	7	4
Rock	0	8
Binds and ironstone	4	0
Coal	0	7
Fire-clay and binds	9	0
	31	7

Dudley Brothers Colliery, between Bloxwich and New Invention.

	FT.	IN.
Batt and fire-clay	6	0
Rock binds	17	10
Black batt	0	6
White rock	1	8
Batt	2	0
White rock	3	0
Black batt	1	7
	32	7

(*See Vert. Sects., sh.* 18, *No.* 29.)

Brown Hills Colliery.

Fire-clay	2
Rock	27
	29

* See Vertical Sections, sheet 16, No. 12, and sheet 26, No. 51.

26. (XXI.) FIRE-CLAY COAL.—We will again take the Stow Heath and Priestfield collieries, between Wolverhampton and Bilston, as the typical locality for the description of this coal. It has there an almost invariable thickness of 9 or 10 feet, with or without a "parting;" and at a distance of 1 to 3 feet below it is another small coal called there "the Little coal." The following is the section of a shaft a little east of Stow Heath Furnace:—

	FT.	IN.	FT.	IN.	
Fire-clay coal, top - -	-	-	6	0	9 feet.
Parting - - -	1	0	-	-	
Fire-clay coal "holers" * -	-	-	3	0	
Slummy batt - -	2	6	-	-	
Little coal - - -	-	-	2	6	
	3	6	11	6	

This thickness and arrangement of beds, with some slight variations, seem to prevail through the Chillington, Rough Hills, and Parkfield collieries down to Coseley, and also about Deepfields, Dockmeadow, and Highfields.

In other places, however, both north towards Bentley and south towards Dudley, the Little coal is entirely wanting, and the Fire-clay coal much altered in thickness. In the northern direction we have the following sections (see Vertical Sections, sheet 16, Nos. 6, 11, sheet 26, No. 45):—

Trentham Colliery, between Wednesfield and Willenhall.†

	FT.	IN.	FT.	IN.
Coal - -			1	2
Parting	1	0		
Coal - -			2	4
Parting	1	0		
Coal - -			0	10
	7	0	4	4
Total with parting			6	4

Sandbeds between Willenhall and Bentley.‡

	FT.	IN.	FT.	IN.
Coal - -			1	2
Parting	0	9		
Coal - -			2	8
	0	9	3	10
Total with parting			4	7

Bentley Heath.‡

	FT.	IN.	FT.	IN.
Coal - -			2	1
Fire-clay	0	7		
Coal - -			1	2
	0	7	3	3
Total with parting			3	10

On the southern side of Stow Heath we get frequent sudden changes even in spots surrounded by places before mentioned. At Friezeland colliery, for instance, just south of Priestfield, there is only "batt and coal, 2 feet," to represent the Fire-clay coal. At Lower Bradley we have "coal and batt, 5 feet," but at Mr. Addenbrook's colliery at Upper

* "Holers" is a term frequently applied to the lowest of a set of coals which are sufficiently close to be "gotten" together. In getting the coal a low wide hole is excavated by the pick some distance into the bottom bed of coal; the upper beds are then cut on each side of this "hole," and, of course, fall into it.

† Communicated by Messrs. Bate. ‡ Communicated by Mr. George.

Bradley, there is a little coal above instead of below the Fire-clay coal, as follows :—

	FT.	IN.	FT.	IN.
Coal - - - -		-	0	6
Black batt - - -	5	0	-	
Fire-clay coal - -		-	5	4
	5	0	5	10

Similar to this is a section at Tipton Green (Vertical Sections, sheet 16, No. 12), where the only representative of the Fire-clay coal is,—

	FT.	IN.	FT.	IN.
Coal - - - -		-	0	3
Fire-clay - - -	5	0	-	
Coal and batt - -		-	2	6
	5	0	2	9

The section at Tipton Moat is the same, except that the lowest coal is only 10 inches thick. At Gornal clay-works there is simply 2 feet of poor coal; at Darlaston the same; and at Dudley Port, 2 feet 6 inches. At the Foxyards, however, we have the two following sections :—

*The Sinking Pit.**

	FT.	IN.	FT.	IN.
Little coal - -		-	1	6
Fire-clay - -	1	6	-	
Coal - - -		-	0	7
Fire-clay - -	2	5	-	
Coal - - -		-	2	7
	3	11	4	8
Total with partings -			8	7

Another Pit.†

	FT.	IN.	FT.	IN.
Coal - - -		-	2	7
Parting - -	1	9	-	
Coal - - -		-	1	4
	1	9	3	11
Total with partings -			5	8

If now we pass into the district south and west of Dudley the same remarks will hold good as to the "Fire-clay" that were used respecting the "New mine coal," but to a still greater extent. There are but five shafts of which I have sections, in which any coal near its place is mentioned. Of these one is the Grave-yard Trial pits,‡ south of Gornal, where below what is supposed to be the New mine coal we get,—

	FT.	IN.	FT.	IN.
Rock and fire-clay - -	5	9	-	
Coal (possibly the Fire-clay) -		-	1	8
	5	9	1	8

* Communicated from Lord Ward's office, by Mr. R. Smith.
† From Smith's "Miners' Guide." ‡ Lord Ward's office.

Two shafts near Corbyns Hall give below what is there believed to be the New mine coal:—

	FT.	FT.	FT.
Fire-clay - -	10 to 12		-
Coal - -	-	-	1
	12		1

At Shut End we get below the supposed New mine coal the following beds:—

	FT.	IN.
Gritty and strong fire-clay -	16	4
Coal and batt - - -	1	6
Hard and white rock - -	10	4
Coal - - - - -	2	8
	30	10

Which (if either) of these may represent the Fire-clay may be reasonably a matter of doubt (see Vertical Sections, sheet 18, No. 31).

At Mr. Gibbons's deep sinking at the Level near Brierley Hill, there was below the supposed New mine coal,—

	FT.	IN.
Fire-clay - - - -	7	0
Clunch with balls of ironstone -	4	0
Binds - - - - -	2	3
Coal and batt, possibly Fire-clay coal	1	6
	14	9

At Mr. Firmstone's deep sinking at the Leys, however, not a trace of coal had been met with below that which we have already designated the New mine, although the sinking was continued for upwards of 77 feet.

27 to 31. (*I.* 10, 11, 12.) ***Measures between the "Fire-clay coal" and the "Bottom coal," including the Getting rock ironstone, the "Poor robin ironstone," and the "Rough Hill White ironstone."*** *

The total thickness of these beds varies commonly from 20 to 30 feet in the district where they are most worked, namely, between Wolverhampton and Walsall. The upper measure is generally fire-clay or clunch, supporting the Fire-clay coal and varying in thickness from 2 to 10 feet. This, however, is sometimes entirely wanting, and the Fire-clay coal rests directly on a "strong rock" or hard sandstone. This rock sometimes contains so much ironstone, either in plates or nodules, as to be worth getting. Beneath this is either more "rock" or else "batt," "clunch," or "binds," several feet in thickness, and then a measure always of argillaceous materials containing either nodules or courses of ironstone, which is the "Poor robin." Immediately beneath this, or sometimes with a few feet of rock, or binds, or clunch interposed, come the Rough Hill White ironstone measures. This ironstone

* By the Getting rock is meant a sandstone which when it contains ironstone is worth getting. I can only refer the origin of the term "Poor robin" to the fantastic imagination of some fanciful collier. The other derives its name from its colour and the locality, the Rough Hills south of Wolverhampton, where it was first worked.

is very local, being only found between Darlaston and Wolverhampton in sufficient quantity to be worth working. At Parkfields, south of Wolverhampton, the whole measure is 19 feet 2 inches thick, with 11 bands of ironstone in it, but elsewhere, even when it occurs, it is rarely more than 2 to 4 feet in thickness.

The following are a few selected sections of this group of beds:—

*Bentley.**

	FT.	IN.
Fire-clay	1	4
Clunch and binds	19	4
Rock	4	0
Binds and clunch	12	2
Clunch and ironstone, probably Poor robin	2	8
Whitestone (iron)	4	11
	44	5

Stow Heath.†

	FT.	IN.
Fire-clay	3	0
Slums	3	0
Getting rock	4	0
Black batt	7	6
Poor robin	2	6
Black batt	9	0
Whitestone	2	3
	31	3

Priestfield.‡

	FT.	IN.
Black clod	10	0
Poor robin	4	0
Light clod	7	0
Whitestone	2	6
	23	6

Ettingshall Lodge.§

	FT.	IN.
Getting rock	4	9
Stratified grey rock	1	4
Batt, inflammable	7	7
Poor robin	3	6
Batt, inflammable	5	0
Whitestone	3	6
	25	8

(*Vert. Sects., sheet* 16, *No.* 8.)

Deepfields.‖

	FT.	IN.
Getting rock	5	0
Poor robin	3	3
Whitestone	3	0
Ironstone balls and gubbin	4	9
Fire-clay	10	6
	26	6

Bradley.¶

	FT.	IN.
Fire-clay	6	0
Rock	0	7
Ironstone balls	1	6
Rock binds	12	6
Poor robin	4	11
Black batt	3	11
Whitestone	3	9
	33	4

If we proceed, from the district thus characterised, farther south, we find one or both of the ironstones quickly disappearing, and the total thickness of the beds diminishing sometimes to only 8 feet. At Highfields for instance, although there is still ironstone, the beds between the Fire-clay and Bottom coals are only two measures of clunch, with ironstone balls, each 4 feet thick.

* Communicated by Mr. George.
† Communicated by Mr. Arthur Sparrow.
‡ Communicated by Mr. W. Ward.
§ Communicated by Mr. Griffith of the Cock-shutts.
‖ From the "Miners' Guide."
¶ Communicated by Mr. S. H. Blackwell.

Elsewhere we get the following sections :—

*Lower Bradly.**

	FT.	IN.
Fire-clay - - -	9	0
Getting rock - - -	9	0
Dark ground - - -	17	6
	35	6

Coseley.†

	FT.	IN.
Rock - - - -	6	6
Ironstone measures - -	4	6
Binds - - - -	5	6
	16	6

Near Cann Lane.‡

	FT.	IN.
Strong rock - - -	28	0
Black batt - - -	3	0
	31	0

*Near Darlaston.**

	FT.	IN.
Brown bastard fire-clay -	10	9
White rock - - -	0	3
Brown clunch - -	6	0
	17	0

The Foxyards.§

	FT.	IN.
Fire-clay rock - -	2	0
Dark rock - - -	3	0
Fire-clay balls (Poor robin?) - - -	3	6
Ironstone (Rough Hills White - - -	2	6
	11	0

Tipton Green.‖

	FT.	IN.
Rock - - - -	9	5
Rock, with balls of iron stone - - -	1	11
Rock - - - -	6	10
	18	2

32. (XXII.) The Bottom Coal.¶—In the part of the coal-field near Wolverhampton, this coal has a pretty uniform thickness of about 12 feet, as in the following section given me by Mr. W. Ward, from a pit a little south of Stow-heath furnace :—

	FT.	IN.	FT.	IN.
**Gainies (inferior coal)	-	-	2	0
Top coal - -	-	-	5	0
Parting - -	-	1 0		—
Holers coal - -	-	-	4	0
	-	1 0	11	0
Total with parting		-	12	0

This condition of the Bottom coal extends generally from Wolverhampton to Willenhall, Bilston, Darlaston, and Coseley.

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* Communicated by Mr. S. H. Blackwell.
† From the "Miners' Guide."
‡ Communicated by Mr. Grogart.
§ Communicated from Lord Ward's office.
‖ Communicated by Mr. Johnson.
¶ This name, assigned to it at first in one locality, turns out, as is often the case, to be a misnomer, as in other localities there are other coals below it, one of which at least is sometimes worth getting.
** Takes its name, I believe, as the bed by which they first arrive at or gain the coal in sinking a pit.

Outside of those limits, however, the variations in the character of the Bottom coal are many and sometimes come in suddenly. Even within those limits we have the following sections :—

*Parkfield.**

	FT.	IN.	FT.	IN.
Coal - -	-	-	4	9
Parting -	0	8	-	-
Holers coal -	-	-	1	0
	0	8	5	9
Total with partings -			6	5

*Ettingshalls Lodge near Catchem's Corner.**

	FT.	IN.	FT.	IN.
Gainies, bad coal	-	-	1	6
Parting batt -	0	4	-	-
Top coal - -	-	-	5	3
Parting batt	10	0	-	-
Holers coal -	-	-	4	6
	10	4	11	3
Total with partings -			21	7

Dockmeadow, south of Bilston Ironworks.

	FT.	IN.	FT.	IN.
Coal - - -	-	-	4	6
Rock - -	6	0	-	-
Rock binds - -	3	0	-	-
Ironstone balls -	1	0	-	-
Rock binds - -	4	0	-	-
Coal, believed to be Holers	-	-	3	0
	14	0	7	6
Total with other beds -			21	6

These three places lie in a straight line about one mile in length, and running nearly west-north-west and east-south-east.

About a mile south of Bilston, at Highfields and Bradley, the Bottom coal is only 3 or 4 feet thick. At Tipton Moat Colliery it is 9 ft. 6 in., from which 2 ft. 6 in. must be deducted for three "parting batts;" at Tipton Green there is said to be "coal and batt," 11ft. 9 in.; and at the Foxyards, 9 or 10 feet of coal. Farther south, however, at Coneygree and Dudley Port, the Bottom coal, if it exist at all, is not more than a foot or so in thickness.

At Shaver's End, just north of Dudley, the following was the section in a trial pit of Lord Ward's :—

	FT.	IN.	FT.	IN.
†Coal - - -	-	-	2	0
Parting - -	0	9	-	-
Coal - - -	-	-	2	0
Parting - -	0	7	-	-
Coal - - -	-	-	0	10
Parting - -	1	0	-	-
Coal - - -	-	-	2	10
	2	4	6	10
Total with partings -			9	2

* Communicated by Mr. Griffiths. † Lord Ward's office.

And at Upper Gornal clayworks, the following beds represented the Bottom coal:—

	FT.	IN.	FT.	IN.
*Coal	-	-	1	6
Parting	0	8	-	
Coal	-	-	0	4
Fire-clay	1	2	-	
Coal	-	-	2	0
	1	10	3	10
Total, including partings			5	8

A mile and a half south of this latter locality, at the Graveyards, in what we have spoken of as the south-western part of the coal-field, we get, below the little coal which we have already supposed to be the Fire-clay coal, a set of beds 28 ft. 5 in. in thickness, alternations of fire-clay, rock, clunch, and binds, and containing two "ball ironstone measures," which may perhaps represent the ironstones of the "Poor robin," and "Rough Hill White;" and below these, a coal 2 feet thick, which may probably represent the Bottom coal.

Similarly at Mr. Gibbons's Level colliery, there was found the following section:—

	FT.	IN.	FT.	IN.
1. Coal and batt, supposed Fire-clay	-	-	1	6
2. Fire-clay	6	3		
3. Strong dark clunch, with balls of ironstone	6	5	20	11
4. Strong white rock	4	0		
5. Broad earth, with balls of ironstone	4	3		
6. Coal	-	-	1	0
7. Black batt	0	5	6	1
8. Fire-clay	5	8		
9. Coal and batt	-	-	1	5
			30	11

Of which beds 2 to 5 may represent those described in the last section (Nos. 27 to 31), and either 6 or 9, or the group of 6 to 9 inclusive, may represent the "Bottom coal." These are the only localities in this south-west district in which, so far as I am aware, any beds that can be compared with the Bottom coal of the Wolverhampton district have been met with.

We may now return to Willenhall, and trace the Bottom coal towards the north and east, namely, to Bentley, Bloxwich, and the Brown Hills. At the Trentham colliery, near Mumber-lane, the Bottom coal assumed the following form:—

	FT.	IN.	FT.	IN.
†Coal	-	-	0	11
Parting	0	3	-	
Coal	-	-	0	5
Parting	0	4	-	
Coal	-	-	0	7

* Mr. J. Kenyon Blackwell. † From Messrs. Bate.

	FT.	IN.	FT.	IN.
Parting - -	0	2	–	
Coal - -	-	-	4	10
Fire-clay - -	1	6	–	
Clod and stone - -	10	0	–	
Rock binds - -	8	0	–	
Batt - - -	2	0	–	
Holers coal - -	-	-	4	6
	22	3	11	3

At Monmore colliery, half a mile east of this, there was—

	FT.	IN.	FT.	IN.
Coal - - -	-	-	3	2
Fire-clay - -	6	9	–	
Rock binds and ironstone	7	8	–	
Fire-clay - -	18	4	–	
Coal, holers - -	-	-	3	3
	32	9	6	5

(*See Vertical Sections, sheet* 18, *No.* 30.)

About Bentley the coals close together again with only a little batt between them, but make a total thickness of not more than 7 or 8 feet. This at the Birch Hills becomes 12 or 14 feet, with only 8 inches of batt; and it retains a thickness of 12 feet towards Bloxwich and Goscott.

For the space of a mile or so between the Birch Hills and Goscott this twelve-foot Bottom coal is called by the colliers the Four-yard or Thick coal, because it is thicker than any other coal thereabouts, and not with any reference to the true Thick or Ten-yard coal, of which most of them know very little, though it is worked within five miles of them.

The outcrop of the Bottom coal may be followed continuously from Bentley acros the Great Bentley fault by Ryecroft to Coal Pool, where it was formerly cut into, and in October 1858 might be seen in a large open work running for about 50 yards on the east side of the brook north-east of Goscott Lodge.

This part of the outcrop was cut off to the northward by a fault having a downthrow to the north of about 10 yards, but the coal had been worked formerly up to Pelsall Heath. Just at the southern corner of Pelsall Heath this twelve-foot coal was known from old workings to separate into two coals of 5 feet and 7 feet. This separation was the consequence of the coming in of some beds of shale and sandstone, which rather rapidly increased towards the north till they attained a thickness of 40 or 50 feet. The Bottom coal, thus separated into two, was worked formerly for some distance along the outcrop north of Pelsall Heath, till it was dropped out of reach of the "old men" by downcast faults into that which may now be called the High Bridge trough. The corresponding upcast faults on the north side of this trough brought these coals again near the surface about the Brown Hills, and they were there gotten both by the "old men," and the men of the last and present generation. All the way along these outcrops of the coals, or wherever they came within a sufficiently slight depth of the surface to be easily worked, they received the name of the Shallow coal and the Deep coal (Vertical Sections, sheet 26, Nos. 41, 42, 43, and 46).

The following are a few of the sections that show this northern expanded form of the Bottom coal :—

Messrs. Davis and Bloomer's Pit, No. 3, *Pelsall Wood Colliery.*

	FT.	IN.	FT.	IN.
Shallow coal - -	-	-	4	0
Fire-clay - -	3	0	–	
Strong clod - -	30	0	–	
Strong rock - -	12	0	–	
Deep coal (roofs) - -	-	-	3	0
Fire-clay - -	2	6	–	
Deep coal - -	-	-	5	0
	47	6	12	0
Total -			59	6

(*See Vertical Sections, sheet* 26, *No.* 43.)

High Bridge Colliery, about a quarter of a mile north-east of "The Moat."

	FT.	IN.	FT.	IN.
Shallow coal - -	-	-	5	2
Fire-clay - -	3	0	–	
Rock binds - -	13	0	–	
Hard grit and peldon -	4	0	–	
White grit rock -	6	0	–	
Rock binds - -	5	9	–	
Hard grit - -	6	0	–	
Deep coal (roof) - -	-	-	1	9
Clod - - -	9	0	–	
Deep coal - -	-	-	4	7
	46	9	11	6
Total -			58	3

(*See Vertical Sections, sheet* 26, *No.* 46.)

Cathedral Colliery, Brown Hills, just south of 120*th milestone on Watling Street.*

	FT.	IN.	FT.	IN.
Shallow coal - -	-	-	6	0
Fire-clay - -	2	0	–	
Strong blue laminated shale	10	0	–	
Rock binds - -	12	0	–	
Strong rock, with dark shades - - -	6	0	–	
Shale, with ironstone layers	11	3	–	
Deep coal (roof) - - -	-	-	0	10
Dark shale - -	3	2	5	0
Deep coal - - -	-	-	5	0
	44	5	11	10
Total -			56	3

(*See Vertical Sections, sheet* 26, *No.* 41.)

Conduit Colliery Brown Hills, north of Watling Street.

	FT.	IN.	FT.	IN.
Shallow coal - -		-	6	0
Bastard fire-clay - -	5	10	–	
Rock binds - -	4	2	–	
Rock, with peldon -	7	7	–	
Rock binds - -	2	9	–	
Rock - - -	2	4	–	
Rock binds - -	25	7	–	
Black batt - -	0	7	–	
Deep coal (roof) - -		-	1	1
Fire-clay - -	3	7	–	
Deep coal - - -		-	5	0
	52	5	12	1
Total -			64	6

(*See Vertical Sections, sheet* 26, *No.* 42.)

Hammerwich Colliery, below the dam of the Reservoir.

	FT.	IN.	FT.	IN.
Coal (shallow) - -		-	7	1
*Warren earth (fire-clay ?)	3	0	–	
Grey leys - -	3	8	–	
Rock binds - -	0	5	–	
Metals (shales) - -	5	7	–	
Rock - - -	4	8	–	
Blue metals - -	0	11	–	
Rock binds - -	0	6	–	
Blue metals - -	3	0	–	
Rock binds - -	0	8	–	
Blue metals - -	1	6	–	
Rock binds - -	0	5	–	
Metals and iron binds -	25	1	–	
Black shale - -	0	6	–	
Coal (roof of deep) - -		-	0	7
Clod - - -	0	6	–	
Coal (deep) - -		-	5	2
	50	4	12	10
Total -			63	2

(*See Vertical Sections, sheet* 16, *No.* 2.)

33. *Measures between the Bottom coal and the Gubbin and Balls ironstone.*—The Bottom coal usually rests on a bed of fire-clay some feet in thickness. In many instances, however, this is wanting, and the coal rests on hard sandstone, the change from one material to the other being sometimes very abrupt. Wherever the Gubbin and Balls ironstone exists, it is found at a distance below the Bottom coal varying from 5 feet to 30 feet, the most usual distance being 15

* Warren earth and some of the other terms used in this section are those common in the Derbyshire, Nottingham, and Yorkshire coal-field.

or 20 feet. The beds between consist sometimes entirely of fire-clay, binds, clunch, or clod, or other argillaceous materials; sometimes these are variously split up by, and interstratified with rock or rock binds, and occasionally these sandy materials almost entirely replace the others. A little coal a few inches thick sometimes occurs in these beds, and the interposed beds of clunch sometimes contain scattered balls or nodules of ironstone.

34. (*I.* 13.) *The Gubbin* and Balls ironstone.*—This set of beds, as a distinct and recognizable measure, containing ironstone worth getting, and regularly "gotten," is chiefly confined to the district around Wolverhampton, Bilston, and Walsall. The following section at Chillington colliery near Wolverhampton gives its best developed form:—

	FT.	IN.	FT.	IN.
Balls of ironstone - -		-	0	8
Clod - - -	2	6	-	
Balls of ironstone - -		-	0	6
Dark clod - - -	1	6	-	
Gubbin ironstone - -		-	0	6
Clod - - -	1	0	-	
Gubbin ironstone - -		-	0	3
	5	0	1	11

(*See Vertical Sections, sheet* 16, *No.* 9.)

Measures similar in character, varying from 5 feet to 10 feet, and containing more or less ironstone, sometimes the Balls, sometimes the Gubbin being absent, and sometimes both found wanting, extend all over the district just mentioned. South of Bilston around Bradley they diminish to about 3 feet. At Tipton Moat colliery there is mentioned "binds with ironstone, 8 feet," about the place of the Gubbin and Balls, namely, at 10 feet below the Bottom coal, but at Coneygree, Foxyards, Gornal, Shaver's End, and the neighbourhood of Dudley generally, there seems no trace of this measure.

The sole vague and uncertain trace of them in the south-western district is the mention in the Graveyard section of "ironstone balls 6 inches," at a depth of 5 ft. 6 in. below what is believed to be the Bottom coal.

Going north towards Bentley, we get, at the Island, the following section:—

	FT.	IN.	FT.	IN.
Balls of ironstone - -		-	0	3
Clunch - - -	2	0	-	
Ironstone - - -		-	0	4
Clunch - - -	1	0	-	
	3	0	1	0

As the representative of this measure in the central part of the Bentley district, and thence by Birch Hills and Bloxwich, there is only mentioned in the pit sections "gubbin 6 inches."

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* I believe this term "Gubbin," which is commonly used in all the Midland coal-fields, is derived from an old English word "gub" or "gob," meaning a piece, lump, or fragment. The waste left after extraction of a coal is called "the gob."

At one part of the Brown Hills, however, near Clayhanger, Samuel Arblaster found under the Deep coal—

	FT.	IN.
Fire-clay and clunch - -	13	6
Gubbinstone, balls of ironstone in two or three layers, and each 6 or 8 inches thick - - -	3	0

At the deep sinking at Haddocks Moor too, near Pelsall Wood, Gubbin ironstone 2 feet 6 inches is mentioned, with 9 feet of Fire-clay between it and the Deep coal, and with a little 6-inch coal immediately under it.

And at the Conduit Colliery at Brown Hills the following beds were found next below the Deep coal :—

	FT.	IN.
Bastard fire-clay - - -	8	0
Black batt - - - -	1	6
Gubbin ironstone measures - -	3	6
Coal - - - - -	0	11

Near Wolverhampton the Gubbin and Balls stone is a very well marked and easily recognizable kind of stone. The large nodules are generally septarian, the septa being lined with white spar, crystals of carbonate of lime and carbonate of iron, together with crystals of iron pyrites, and not unfrequently of both galena and zinc blende.

35. *Beds below the Gubbin and Balls, including* 36. (XXIII.) *the "Singing" or "Mealy-greys" coal.*—Wherever the Gubbin and Balls is mentioned in the sections as a recognizable measure, there is found just below it either a little bed of pure coal 6 or 8 inches thick, or a bed of "slum" (batty coal), which is often 2 or 3 feet thick, and sometimes more. In Cockshutts colliery only is there a thin bed of sandstone between this coaly material and the Gubbin and Balls.

At a distance below the Gubbin and Balls, which varies from 18 to 50 feet, there occurs a coal 2 to 4 feet in thickness, which is called sometimes the Singing* coal and sometimes the "Mealy-grey"† coal.

In the Wolverhampton district the thickness of the beds between the Gubbin and Balls and the Singing or Mealy-greys coal seems never to exceed 24 feet, nor fall below 18 feet, except where a bed of green rock or trap interposes. At Trentham new colliery, north of Willenhall, however, these beds are 35 feet, and towards Bentley, at "the Island," half a mile east of Willenhall, it is 50 feet, as also at the Monmore colliery. Farther north-east, however, about Birch Hills and Bloxwich, the thickness again diminishes to 33 feet or 26 feet, and the Singing coal itself is only 10 inches or 1 foot in thickness. At Haddocks Moor, the most northern locality where this coal has been pierced, it was found to be 1 foot 4 inches in thickness, and to lie at a depth of 48 feet 6 inches below the Deep coal, or 37 feet below the Gubbin ironstone. They passed also through another little 6-inch coal at a depth of 34 feet below the Mealy-grey coal.

In the part of the field south of Bilston there is but little mention of this coal, but it appears in a section at Tipton-green,‡ where, at a depth

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* This name was described to me as arising from the fact, that as they passed through it in some places, the gas could be distinctly heard issuing from its crevices "like the singing of a tea-kettle."

† Where it has this designation, it is said to be of a greyish hue and to be partly friable or "mealy."

‡ Given me by Mr. Johnson of Dudley.

below the Bottom coal of 37 feet (excluding trap) there is "Singing coal 4 feet." If from this we take off a portion to include the Gubbin and Balls, &c., the remaining thickness will be very nearly equal to what these beds have near Wolverhampton.

In some parts between Wolverhampton and Bilston I believe the Singing or Mealy-greys coal is now "gotten" (1852), and is looked on by the iron-masters as a valuable help to their resources.

The materials composing the beds just described are generally an alternation of fire-clay, clunch, or binds, with rock or rock binds, sometimes the argillaceous, sometimes the arenaceous character predominating. In the neighbourhood of Bentley one or two little coals a few inches thick likewise show themselves.

37. *Measures between the Mealy-grey coal and the Blue-flats ironstone.*—Below the Singing or Mealy-grey coal we get a mass of beds consisting sometimes entirely of fire-clay, more frequently of alternations of fire-clay and rock, varying in thickness from 16 feet to 50 feet, before we reach the Blue-flats ironstone. As in the case of the beds above described, these measures are also thickest in the Bentley district, where they contain also one or two little beds of coal, and in their lowest portion some ironstone balls. The alteration in thickness in these beds is sometimes rapid, as in a colliery at Portobello near Wolverhampton, in two pits within 150 yards of each other, the beds consisting in both of fire-clay and rock, varied from 16 feet to 29 feet in thickness. Elsewhere about Wolverhampton they have a pretty constant thickness between 20 and 25 feet.

The two groups of beds, namely, those above and those below the Singing or Mealy-grey coal, while they each vary in thickness in different places, usually vary in such a way as to balance each other and maintain a certain mean aggregate thickness.

The aggregate thickness of the whole beds between the Gubbin and Balls, and the Blue-flats ironstones is, near Wolverhampton, never more than 53 feet nor less than 40 feet (exclusive of trap); but north and east of Willenhall, around Bentley, and up to Bloxwich, it is never less than 70 feet, and sometimes reaches 85.*

It will be important to bear these facts in mind when we come to describe the trap rocks which have been intruded into these beds.

38. to 42. (*I.* 14, 15, 16.) *The Blue-flats ironstone, together with the Diamonds and Silver threads ironstones.*—We have now to describe the lowest recognizable measures in the whole of the South Staffordshire coal-field, those beneath which neither coal nor ironstone have ever been found that were of the least value.

The Blue-flats ironstone is confined absolutely as a workable measure to the district between Wolverhampton and Walsall, scarcely going south of Bilston, nor so far north as Bloxwich. It is an easily recognizable ironstone, as it occurs usually in regular bands a few inches thick, which are smoothly jointed, and are but slightly concretionary in structure. When brought to the pit bank the lumps of ironstone look like large rather irregular bricks; they are pale brown at first, but from

* In Samuel Arblaster's pit near the Brown Hills before mentioned, they got some ironstone somewhat resembling the Blue flats at a depth of only 12 feet (white tender rock) below the supposed Gubbin and balls. The identification of the measures, however, is too doubtful for us to found any argument on.

exposure to the air assume a dull blue or purplish look. This colour, joined to the flat pavement-like form in which they are found below, gives them their name.

The ironstone usually occurs near Wolverhampton in two, three, or four regular bands, interstratified with clunch or clod, as in the following sections:—

*The Cockshutts.**

	FT.	IN.	FT.	IN.
Clod	4	0	–	
Ironstone	–		0	4
Clod	2	0	–	
Ironstone	–		0	2
Clod	3	0	–	
Ironstone	–		0	3
	9	0	0	9

Park Hall.†

	FT.	IN.	FT.	IN.
Top stone	–		0	6
Binds, &c.	2	0	–	
Second stone	–		0	3
Parting	1	3	–	
Third stone	–		0	4
Ground with chitterstone	4	2	–	
Bottomstone	–		0	3
	7	5	1	4

Chillington.‡

	FT.	IN.	FT.	IN.
Stone	–		0	5
Clod	1	0	–	
Stone	–		0	5
Clod	0	6	–	
Stone	–		0	2
	1	6	1	0

The Blue flats are mentioned with a thickness of about 3 feet a Deepfields and Bradley, and as 5 feet thick at Darlaston; but what proportion of ironstone they contain there I do not know.

In some places near Wolverhampton mention is made of the "Bristol diamonds ironstone," just below the Blue flats. It seems there to be very poor and trifling; but as we proceed to the north-east we find around Bentley and Walsall the Diamonds ironstone as rich and important as the Blue flats, and, moreover, the "Silver threads" coming in between them, with much ironstone in bands and cakes in the intervening

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* Mr. Griffiths. † Lord Ward's office.
‡ Murchison's Silurian System.

measures. The section here is of a totally different character from that near Wolverhampton, as may be seen by the following examples :—

*Bentley Estate.**

		FT.	IN.	FT.	IN.
Blue flats	Ironstone			0	4
	Binds	3	0		
	Ironstone			0	1
	Binds	1	6		
	Ironstone			0	2
	Binds with ironstone nodules	9	8		
Silver threads	Ironstone			0	1
	Binds	1	0		
	Binds with ironstone	3	4		
	Ironstone			0	2
	Binds	6	0		
Diamonds	Ironstone			0	3
	Binds	1	4		
	Ironstone			0	2
	Binds	1	5		
		27	3	1	3

(*See Vertical Sections, sheets* 16 *and* 26, *Nos.* 6, 40, *and* 45.)

Ryecroft, north of Walsall.†

		FT.	IN.	FT.	IN.
Blue flats	Ironstone cake			0	3
	Blue clod	1	0		
	Ironstone			0	3
	Blue and white clod	3	7		
	Ironstone balls, called grandads			0	8
	White clod	10	0		
Silver threads	Ironstone			0	3
	White clod	2	8		
	Ironstone			0	4
	White clod	3	0		
	Ironstone			0	3
	White clod	7	6		
	Balls of ironstone (sometimes)			0	8
	White clod	7	0		
Diamonds	Ironstone			0	3
	Black clod	2	0		
	Ironstone			0	4
		36	9	3	3

(*See Vertical Sections, sheet* 16, *No.* 7.)

Going still farther north, again, the ironstones seem to be rapidly dying out and disappearing. At Dudley Brothers colliery, for instance, about half a mile west of Bloxwich, although these measure were still recognizable, they contained so little ironstone as not to be worth working ; while around Pelsall they sank at one place 150 feet below the Bottom coal without finding either coal or ironstone, till at that

* Mr. George. † Mr. Arthur Sparrow.

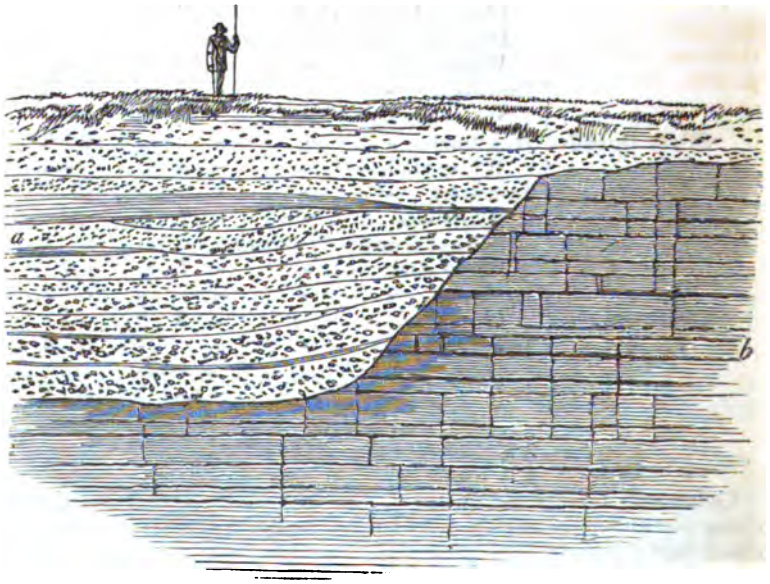
depth they came on a little "lean" ironstone, which was conjectured to represent the Blue flats.

43. *The base of the Coal-measures.*—It remains now only to investigate the nature and thickness of the beds that lie below the Blue flats and other ironstones, or, where those measures are not present, the lowest beds of the Coal-measures in each locality.

I may premise, that in the cutting of the railway near Trindle Gate, just east of Dudley, the base of the Coal-measures was very well exposed, resting on the Silurian shale, and exhibiting the following facts.

The Coal-measures here consisted of pale yellowish sandstones, many of them argillaceous (rock binds), with some small beds of shale or clay. The Silurian shale was a compact blue shale in thick beds, lying very regularly in a nearly horizontal position. At one part of the section some of the upper beds of the Silurian shale ended in a moderately sloped cliff, against which the sandstone of the Coal-measures abutted, while they reposed on the lower beds of shale that continued beneath them. As both groups of beds were nearly horizontal, no unconformity could be perceived between them, except just at the little Silurian cliff. Here the lamination of the sandstones became oblique, trying to conform to the slope of the cliff, and the lower beds of it, both near the cliff and for some yards back, contained pebbles and many small angular fragments. The pebbles were mostly white crystalline quartz, with some rolled pieces of ironstone. The angular fragments were chiefly Silurian shale and limestone. The cliff was about 20 feet high (see Fig. 11.)

Fig. 11.



a Coal-measures. *b* Silurian shale.

From this very instructive instance we learn generally how, with perfect apparent local conformability, there may be still on the large

scale a very great amount of unconformability between two formations, and in this special case we see the nature of the relation between the Coal-measures and the Silurian rocks of the South Staffordshire coal-field; that the Silurian rocks were greatly denuded and worn away, and cliffs and hollows formed in them, on, against, and over which the Coal-measures were deposited, both lying in a nearly horizontal position.

In the district south and west of Dudley there has been no pit sunk from any of the known beds of the Coal-measures down to the Silurian, unless they reached that formation in the Blackheath colliery, south of Rowley Regis (see Vertical section, sheet 18, No. 26). In that abortive search for valuable coal or ironstone, they reached, at 570 feet from the surface, the representative of the Thick coal in a debased and worthless form, and they sank to a depth of 121 feet below it, meeting with only a few trifling beds of coal or ironstone. At a depth of 661 feet from the surface, and 81 feet below the Thick coal, they met what is described as "red parting and limestone, 1 inch," and below that they found thick and regular beds of "rock binds," separated by inch partings of white clay. Now if the sinkers had never before worked in the Silurian rocks they might easily have described those as "rock binds," and they bored through *precisely similar materials* for 300 feet below the bottom of the shaft. This statement makes it very probable that the last 340 feet out of the 1,001 feet passed through altogether, consisted of Silurian shale, since it is totally contrary to the nature of the South Staffordshire Coal-measures to maintain one lithological character through so great a thickness. If these rock binds were Silurian shale, then there was only 81 feet of Coal-measures between it and the Thick coal in that locality.

The nearest deep sinking to this that I am aware of is the one at the Level colliery north-east of Brierley Hill, made by Mr. Benjamin Gibbons, and quoted by Sir R. I. Murchison in his Silurian System, p. 478. Of this pit we have already investigated the details, and endeavoured to identify the lower coals. The following abstract will give us all further necessary information about it:—

	FT.
To the bottom of the Thick coal - - -	240
To ditto of 2nd Heathen ditto - -	18
To ditto of Stinking ditto - - -	34
To ditto of New mine (?) ditto - -	37
To ditto of Fire-clay (?) ditto - -	15
To ditto of Bottom ditto - - -	29
To ditto of (small coal and batt 8 in.) -	19
Alternations of "rock," fire-clay, clunch, and binds, varying from 2 feet to 10 feet each - -	109
Dark gritty rock, with conglomerate - -	26
Light blue clunch - - - - -	3
Below which they bored in *red clunch* - -	60
	590

Making a total of 217 feet below the Bottom coal, or 350 feet below the Thick coal, without meeting with anything that appears like Silurian rocks.

At the Leys ironworks, north-west of Brierley Hill, Mr. Firmstone sank a pit, as follows :—

	FT.
To the bottom of the Thick coal - - -	492
To ditto of Heathen ditto - - -	9
To ditto of Stinking ditto - - -	10
To ditto of New mine (?) - - -	24
Beds of fire-clay, rock, binds, redand grey clod, and *red rock*, 1 foot to 7 feet each - - -	39
Red sandstone grit full of pebbles - - -	38
	612

Making a total of 120 feet below the Thick coal; having reached which depth the water burst in on them with such force and rapidity as to oblige them to abandon the sinking.

It is singular that in each of these pits, although at different depths, the lowest beds were red, clunch in one case, (which might be marl,) and sandstone in the other. One might speculate on some beds belonging to the Old red sandstone having come in, were it not that many of the true Coal-measures, both above and below the Thick coal, contain much red and mottled marl and clunch.

At Corbyns Hall Mr. Gibbons sank 172 feet below the Thick coal, the bottom beds being alternations of clunch and rock binds, when a quantity of *salt water* rushed in with such force as nearly to drown the mines.

At Shut End mines Mr. Foster sank 111 feet below the Thick coal, passing 16 feet below the representative of the Fire-clay coal, and found much of the water in the lower measures very salt.

The following is a complete abstract of the Graveyard Trial pits, south of Lower Gornal :—

	FT.
To bottom of Thick coal - - - -	43
„ „ Heathen do. - - - -	15
„ „ Sulphur do. - - - -	43
„ „ New mine do. - - -	24
„ „ Fire-clay - - - -	8
„ „ Bottom - - - -	40
To bottom of another little coal passing through many beds of rock, &c. - - - -	112
Several beds of rock - - - -	21
	306

(*See Vertical Sections, sheet* 18, *No.* 23, *lower part.*)

Making a total of 133 below the Bottom coal, or 263 feet below the Thick coal, without attaining the base of the true Coal-measures.

For ascertaining the exact thickness of Coal-measures between any known bed and the top of the Silurian formation in any part of the field, we have but scanty data in the pit sections. Even where it is certain, or highly probable, that the sinking was continued down into the Silurian rocks, we are often left to guess at the place of the exact boundary between the two formations, since the miners are but little

apt to observe any distinction between the grey shales of the coal-measures and the shales of the Silurian series. Where the latter also are at all hard, or slightly arenaceous, the miners are likely to call them "rock binds," and we are thus liable to class them as Coal-measures. Mention, too, is sometimes made in the sections of a "blue rock;" now, whenever I have seen any beds thus described, I have always found them a compact slightly arenaceous clay rock, so greatly indurated as to form a hard tough stone: and, in sinking a shaft, the Silurian shale of this neighbourhood would be likely often to have these characters, and thus be called by the miners "blue rock." Whenever there is a white or strong brown rock mentioned, I should always consider it as part of the Coal-measures, because I have never seen or heard of any sandstones of that colour in the Silurian shales of this district; and if it were limestone rock, they would almost certainly have described it as such.

With these remarks I now lay before the reader the following ten extracts from pit sections, beginning at the most southerly, and proceeding to the north and east:—

1. *Shaver's End, just north of Dudley.*

	FT.	IN.	
Bottom coal	9	2	
Rock and clunch	39	0	68 ft.
Ironstone measure may = Blue flats	7	0	68 ft.
Fire-clay, rock, and pebbly rock	22	0	68 ft.
Blue clunch	4	0	
Bavin and limestone	72	0	
	153	2	

(*Vert. Sects., sheet* 18, *No.* 36.)

2. *Dudley Port, Bagnall's Limestone Pit.*

	FT.	IN.
Bottom (?) coal	1	6
Fire-clay, black ground, rock binds, and rock	60	0
Bavin (Silurian shale)	69	0
Limestone	27	0
Limestone	24	0
	181	6

(*Vert. Sects., sheet* 16, *No.* 13.)

3. *Tipton Green.*

	FT.	IN.	
Bottom coal	11	9	
Fire-clay, rock, &c.	37	0	71 ft.
Singing coal	4	0	71 ft.
White rock and pebbles	30	0	71 ft.
Blue binds	130	0	
	212	9	

(*Vert. Sects., sheet* 16, *No.* 12.)

4. *Foxyards.*

	FT.	IN.	
Bottom coal	9	0	
Fire-clay, black ground, and rock	80	0	92 ft.
Ironstone (Blue flats?)	4	6	92 ft.
Strong pebbly light coloured rock	7	6	92 ft.
Strong blue rock	36	0	
	137	0	

5. Tipton-moat.

	FT.	IN.
Bottom coal - -	9	6
Fire-clay, black ground, binds, and ironstone, batt and coal, white rock, &c. - - -	71	0
Blue rock and binds	112	6
Binds - -	17	0
Stone and binds -	172	0
	382	0

6. Deepfields.

	FT.	IN.	
Bottom coal	12	0	
Rock, clunch, and rock binds -	69	0	71ft. 6in.
Blue flats -	2	6	
Blue rocky clunch	150	0	
Limestone -	50	0	
	263	6	

7. Parkfield, near Wolverhampton.

	FT.	IN.	
Bottom coal -	11	2	
Various coal-measures -	68	0	133ft. 6in.
Blue flats -	10	9	
Diamond clod	2	3	
Strong white rock -	22	6	
Dark slaty ground -	30	0	
Limestone bavin			
	144	8	

(*Vert. Sects., sheet* 17, *No.* 20.)

8. Chillington Colliery, near Wolverhampton.

	FT.	IN.	
Bottom coal -	12	1	
Various coal-measures -	89	0	91ft. 6in.
Blue flats -	2	6	
Measures undescribed	240	0	
Limestone clunch, with small bands of limestone	210	0	
	553	7	

(*Vert. Sects., sheet* 16, *No.* 9.)

9. Bentley Limestone Pit.

	FT.	IN.	
Bottom coal -	8	8	
Various coal-measures -	89	0	146 ft.
Blue flats, Silver threads, and Diamonds	28	0	
Binds, fire-clay, and rock	29	0	
Binds and parting, Silurian	117	0	
Binds with thin limestones -	97	0	
Little limestone	12	0	
Shales with limestone -	118	0	
Thick limestone	33	9	
Shales with limestone -	18	0	
	550	5	

(*Vert. Sects., sheet* 16, *No.* 6.)

10. Ryecroft.

	FT.	IN.
Blue flats, Silver threads, and Diamonds - -	41	6
Rough rock - - -	6	0
Limestone, clunch, binds, and partings - -	183	0
Little limestone - -	12	0
Limestone clunch, with hard limestone balls -	120	0
Thick limestone - -	36	0
	398	6

(*Vert. Sects., sheet* 16, *No.* 7.)

In the first six of these sections there is a remarkable agreement in the total thickness of Coal-measures below the Bottom coal, supposing that in each case the "blue binds" or "blue rock," from its colour and its preserving a uniformity of structure through so much greater thickness than the Coal-measures usually do, be the Silurian shale. At Parkfield (No. 7), the beds below the Bottom coal are thicker than elsewhere, in consequence of the extra thickness in those between the Blue flats and the Silurian shale. At Chillington (No. 8), we have no means of ascertaining this point, or of saying anything more than that they were in the Silurian shale when they got down 240 feet below the Blue flats.

At Bentley, the Coal-measure beds below the Bottom coal have thickened to 146 feet, with 30 feet below the Blue flats group, while at Ryecroft there is only 6 feet of Coal-measures between that group and the top of the Silurian shale.

In all cases, the lowest beds of Coal-measures, where ascertainable, were found to be sandstone, generally containing pebbles.

Thickening in the lower beds of the Coal-measures as they range from south to north.—In page 20 is given a table of the beds, with the minimum and maximum thickness of each, as described in the foregoing pages. If, looking at those below the Thick coal, the minima were added together, we should only have a thickness of 98 feet for the whole of the beds between the bottom of the Thick coal and the top of the Blue flats. If the maxima were added, on the contrary, we should have a total thickness of 539 feet. The mean of these two numbers is 318. Now it is a remarkable instance of the way in which the frequent variations in the thickness and character of the beds are equalized among themselves, and a certain mean thickness kept, that the mean of 13 pit sections, distributed pretty equally over various parts of the district, gives 322 feet as the actual mean thickness of the beds between the base of the Thick coal and the top of the Blue flats. If, moreover, we arrange these 13 sections in the order of their thicknesses, we shall find that that will very nearly be the order of their latitude, the thinnest section being the most southerly and the thickest the most northerly; the others being nearly regularly arranged between them. I add at the beginning a section still further south, at Foxyards, where it was doubtful whether the ironstone were the Blue flats or not; the probability of its being so having become much greater from the way in which it harmonizes with the other sections.

	Thickness between the Thick Coal and Blue Flats in Feet.
1. Foxyards	240
2. Bradley	270
3. Deepfields	274
4. Crabtree piece, near Bilston	290
5. Stowheath	300
6. Friezland	302
7. Stowheath	306
8. Chillington Colliery	312
9. Rough Hills	329
10. Priestfield	333
11. Ettingshall Lodge	336
12. Bentley Estate	365
13. Bentley, another shaft	378
14. Bloxwich	395

This exhibits very clearly what has been before alluded to in describing these beds, the gradual thickening of them towards the north, the total section being 150 feet greater at one end than the other.

If we were to take the thickness of the beds from the base of the Thick coal to the base of the Bottom coal, we should get precisely similar results as a whole. As, however, we possess 30 sections, which include the necessary data for the Bottom coal, while we have only 13 for the Blue flats, we should expect to find one or two of them a little out of their place, owing to partial and strictly local thickening or thinning of a few beds simultaneously, while generally these variations in thickness balanced each other. I add this list arranged in order of thickness :—

	FEET.	
*1. The Graveyards	120	The south-western district.
2. The Level	133	
3. Upper Gornal	133	
4. Foxyards	159	Between Dudley and Wednesbury.
5. Tipton Green	160	
6. Coneygree	167	
7. Tipton Moat	167	
8. Bradley Lodge	176	All between the latitudes of Coseley and Bilston.
9. Ettingshall, near Cann-lane	176	
10. Highfields	194	
11. Highfields	196	
12. Highfields	203	
13. Deepfields	205	
14. Bradley	213	
15. Dockmeadow	216	
16. Priestfield Furnace	225	All on or about the latitude of Bilston.
17. Bilston Meadow	228	
18. Priestfield Colliery	229	
19. Friezland	232	
20. Crabtree Piece	240	
21. The Wallbutts	242	
22. Chillington Colliery	250	All north of Bilston, near Wolverhampton.
23. Stowheath	253	
24. Rough Hills	256	
25. Bentley Heath	263	Still farther north.
26. Bentley Hall	265	
†27. Lower Bradley	266	South of Bilston.
‡28. Ettingshall Lodge	270	Due west of Bilston.
29. Bentley, northern part	276	North of 26.
30. Bloxwich	291	North of 29.

It follows, from an inspection of this list, that our identification of the Bottom coal in the three sections in the district south and west of Dudley, namely, Nos. 1, 2, and 3, that identification being founded only on the details of the sections, is rendered still more probable, from its harmonizing so well with our general results. It agrees, also, well with the statements before given as to the splitting up and separation of the Thick coal towards the north, and the coming in of other beds in that direction not known towards the south, and shows that the

* In geographical order the Graveyards would come between Nos. 2 and 3.

† The abnormal position of this section is due to a local thickening of the beds between the Thick and Heathen coals.

‡ Due to a local increase in the thickness of several of the measures, which is compensated for in the beds below the Bottom coal, as in the Blue flats list this section takes its proper geographical position.

thickening in those upper measures is only a still further carrying out of a structure or character common to the whole coal-field.

Connexion of the Wyrley and Essington district with the rest of the Coal-field.—We have now given a detailed description of the beds constituting the Coal-measures of the central and southern portion of the field, and have traced the lower beds in detail as far north as the Brown Hills.

The Heathen and Sulphur coals were also traced in detail up to the neighbourhood of Bloxwich, and have been mentioned as forming the uppermost measure in some of the more western pits in the Brown Hills district.

The dip of the beds from Bentley to Bloxwich, and from Bloxwich all over the Pelsall and Brown Hills district is from east to west, at a low but steady angle of inclination. The dip of the beds at Essington and Wyrley is likewise from east to west at the same gentle angle. It follows that unless there be a great fault or a great flexure running north and south between Pelsall and Essington on the one side, and the Brown Hills and Wyrley on the other, that the beds which are worked along the eastern side of this portion of the field dip under those that are worked on the western side, and would be found underneath them if a sufficiently deep sinking were made.

Two such explorations have been made, as will be seen presently, one a boring and the other a shaft, and though not quite conclusive in their results, are yet in favour of that belief as far as they go.

Neither from Bentley nor from Pelsall have there been any continuous workings up to Essington and Wyrley, a width of a mile and a half or two miles of unexplored ground isolating the Essington and Wyrley collieries from the rest of the coal-field. It is believed, from some sinkings that were made formerly near the New Invention, and from other appearances, that this belt of unexplored ground is greatly cut up by sheets and masses of trap rock. We are accordingly left to the following evidence in order to connect the Essington and Wyrley beds with the other beds of the coal-field, and prove the statement made in the General Description (Chapter V.), that the coals there represent the Thick coals.

We have seen that the Bottom coal and the beds immediately above it are worked continuously from the neighbourhood of Bilston and Wolverhampton under the Bentley and Bloxwich districts, up to Pelsall and the Brown Hills; and that as they range from the former towards the latter, the measures increase in thickness, and beds which lie together in the southern part are, as they run north, split up by intervening measures and sometimes widely separated from each other. It will be remembered also that between Bilston and Wolverhampton the Thick coal has already lost the two upper beds, which have gone off as the Flying reed, and cropped out south of the Lanesfield fault, and that the remaining part is also separated into two masses by an intervening bed of shale 10 feet thick, called "Hob and Jack."

The measures rise from this district gently towards the north, the Thick coal cropping out directly, and the beds below it gradually and successively until at Bentley Hall and Deepmore Coppice the Bottom coal is but a little way below the surface of the ground.

A little north of Deepmore coppice a great fault running nearly east and west throws down the measures to the north to the extent of 360 feet so that the Bottom coal is then about 400 feet deep, with all the measures above it easily recognizable up to the Heathen coal, which is there about 144 feet deep. Now, as the Heathen coal about Bilston is never more than some 30 feet below the Thick coal, it follows that we

ought to have, north of the Bentley fault, the Thick coal itself some 80 or 90 feet at least below the surface. What is really found there is the following :—

		FT.	IN.	FT.	IN.
1.	Soil, gravel and clay	-	-	21	11
2.	Coal (called Old man's coal)	-	-	9	7
3.	Fire-clay, clunch, rock, and binds	54	0		
4.	Little coal	1	10	56	6
5.	Fire-clay	0	8		
6.	Coal (called Bentley Hey coal)	-	-	5	0
7.	Fire-clay, rock, and binds	10	1		
8.	Ironstone (called the Binds)	1	7		
9.	Coal (called the Binds coal)	1	2		
10.	Clunch and binds	6	6		
11.	Gubbin ironstone	1	9		
12.	Gubbin coal and batt	1	2	47	9
13.	Fire-clay	0	10		
14.	Coal	0	7		
15.	Binds	21	0		
16.	Clunch and ironstone (Lambstone)	3	0		
17.	Black batt	0	11		
18.	Coal (Heathen coal)	-	-	1	8
				143	3

Of this set of beds, No. 11 is the same as the Little Gubbin, already described, farther south. It has, however, here two small coals below it, and the thickness between it and the Heathen coal is 4 or 5 feet greater than the thickness about Bilston.* There is above the Little Gubbin, moreover, another small coal and ironstone (here called the Binds coal and ironstone), of which we have little or no trace to the southward ;† and we must look upwards of 19 feet above the Little Gubbin (instead of only 5 or 6, as near Bilston,) before we meet with any considerable bed of coal. We then get two beds of coal, (Nos. 4, 5, and 6,) 7½ feet thick together, including 8 inches of fire-clay between them, over which are 54 feet of alternations of fire-clay, clunch, binds, and rock, and then another bed of coal 9 or 10 feet in thickness. It is clear, nevertheless, from their position above the Heathen coal, that these latter coals, namely, No. 6, the "Bentley Hey," and No. 2, the "Old man's" coal, notwithstanding their being 54 feet apart, must be the representatives of the lower beds of the Thick coal.

Now, the Bentley Hey coal, and the Heathen coal below it, are found at intervals, and worked, north of Bentley, up to the New Invention and Bloxwich. They have never been worked quite continuously, as they are said to be frequently thrown in and out of the ground, not only by a succession of small faults and one large one, but also by several undulations of the beds.

The Bentley Hey four-foot coal has also been worked north of the New Invention, with a general dip to the west or W.N.W., that is in the direction of Essington.

In the cutting of the canal, just south of Sneyd Reservoir, the crop of a coal was seen which Mr. George, of Bentley, now informs me he

* It will be recollected that some distance south of Bilston, around Dudley for instance, the beds between the Little Gubbin and the Heathen coal thin out to nothing, and the ironstone measures rest directly on the coal.

† There are sometimes small beds of ironstone both above and below the Little Gubbin in the southern part of the field, as at Claycroft, near Dudley, see p. 54.

believe to be this same Bentley Hey coal, and that its crop runs off towards Moseley Field; the dip being very gentle towards Essington. Now supposing that it dips at an angle of 3° from the canal, just by Sneyd Pool, to Mr. R. Mills's Essington colliery, and that the ground was quite level, which it is nearly, and allowing the distance in a straight line to be $1\frac{4}{10}$ mile, or nearly 7,400 feet, the depth of this coal would be 392 feet from the surface at the Essington colliery. It would, however, have to cross the Old Mitre fault, which is a downthrow to the west of 65 yards (or 195 feet) thereabouts, so that the total depth of the coal would be (392 + 195 = 587 say) about 600 feet. Moreover, this Bentley Hey four foot-coal has in the Great Bentley trough another coal, called the Old Man's coal, 8 or 9 foot thick, at the height of 54 feet above it.

Now at the Essington colliery a Four-foot coal was found at a depth of 593 feet, and 38 feet above it was found a compound seam of coal, 8 feet 7 inches thick.

The probability is considerable that these are the very same coals which are known at Bentley as the Old man's 9 foot coal, and the Bentley Hey or Top four-foot coal.

Now, over this coal at Essington come all the Wyrley coals, presently to be described, and known as the Broach, Cannel, Charles, Yard, and Robins, all in their proper places, which proves this coal to be that which at Wyrley is called the Bottom coal or Eight-foot coal.

This coal which at Wyrley is called the Eight-foot or Bottom coal (because it is the lowest coal that has ever been worked in that district) is known all over the Essington and Wyrley district, and it is known to crop out finally* about Jacob's Hall, and along a north and south line running parallel to and a little east of the turnpike road between Bloxwich and Clunch Bridge.

The late Mr. Gilpin had a boring made below the so-called Bottom coal, of which his agent, the late Philip Baker, of Landywood, gave me the following account:—

	FT.	IN.
Coal (called Bottom coal) - -	7	0
Clunch with occasional ironstone -	40	7
Coal - - - - -	3	0
Fire-clay with alternations of clunch and rock - - -	113	6
Coal - - - - -	2	3
Clunch with small ironstones and some beds of rock - -	68	8
Coal - - - - -	1	5
Clunch with little ironstones and some rock - - -	38	3
Coal - - - - -	2	0
Fire-clay, rock, and clunch - -	30	2
Coal - - - - -	0	4
Fire-clay and clunch - -	10	2
Coal - - - - -	1	6
Fire-clay and clunch - -	4	2
	323	2

* I say finally, because the whole district is broken up by a multitude of faults, so that all the coals crop and are thrown in again several times. The lines, therefore, drawn on the map about Wyrley and Essington must be taken rather as marking the general limits than the actual outcrop of the coals, while it has hitherto been found impracticable to delineate the numerous faults on the small scale of the Ordnance map.

The present Mr. Gilpin sank a shaft, at a place called Highfields, a little south of Church Bridge, to the depth of 211 feet (70 yards) below the so-called Bottom coal, of which the following is an abstract of the particulars as he communicated them :—

	FT.	IN.
Coal (called Bottom coal) - -	8	0
Fire-clay, black batt, and brown ironstone - - -	4	1
Coal - - - - -	0	6
Binds, clod, &c. with ironstone -	32	5
Coal - - - - -	3	0
Fire-clay, binds, &c. - -	26	0
Coal - - - - -	1	0
Fire-clay, clunch, binds, &c. -	132	6
Coal (stinking) - - -	1	2
Fire-clay - - - -	2	0
	210	8

The boring I esteem valuable solely as proving there was that much depth of Coal-measures below the Bottom coal, for I have long come to the conclusion that all indications of thickness of particular beds, &c. derived from borings are too uncertain to be depended on.

The existence of a Three-foot coal, however, about 37 or 40 feet below the Wyrley bottom or Eight-foot is proved from both the boring and the sinking. This is without doubt the Bentley Hey coal. The sinking places a foot coal at 26 feet below this Three-foot, and if the latter be the Bentley Hey coal the foot coal may possibly be the Heathen. At a depth of 132 feet 6 inches underneath this there is, according to the sinking, a coal called Stinking, 14 inches thick. This may very well be the true Stinking or Sulphur coal, which in the southern part of the field lies at a mean depth of 70 feet below the Heathen, though it is not more than 50 or 60 feet below it at Bentley and the Birch Hills.

I believe that Mr. Gilpin himself was convinced that the Stinking coal which he reached was the Top or Two-foot coal of the Brown Hills, which is almost certainly the true Sulphur coal, basing his opinion not only on the sulphureous quality of the coal, but on the occurrence of some ironstone measures above it, believed to be the Pennystone measures, and another which was recognized or supposed to be recognized as the New mine ironstone clod, although it was devoid of ironstone. If this be the Stinking coal, it follows that the Brown Hill and Pelsall coals may be found below it. In this opinion I entirely concur, though it is impossible to feel sure that the lower beds will retain the same thickness and value in the deep or western side of the field which they have on the eastern side.

If there should still rest any doubt upon anybody's mind as to the Wyrley and Essington coals being the representative of the Thick coal in an expanded form, perhaps the following argument may be conclusive. If these coals be other than the Thick coal they must be either above it or below it. If they are entirely above it then the Thick coal must lie in the district between Essington and Wyrley on the one side and Pelsall and the Brown Hills on the other, and must crop out to the surface in that district, inasmuch as beds, which are *certainly below* the Thick coal, themselves crop out to the eastward of it. It is not very likely, indeed we may say it is quite impossible, that such an outcrop of Thick coal could exist without having been long ago dis-

covered, ranging, as it must do, for a distance of several miles between Bloxwich and Norton.

If, on the other hand, it be supposed that the Wyrley and Essington coals belong to the beds below the Thick coal, then we have at the Essington colliery a thickness of nearly 600 feet of coal-measures full of good workable coals, to which we must add 280 feet for the depth of Mr. Gilpin's boring below the Three-foot coal which lies 40 feet below the so-called Bottom coal. We should then have a thickness of nearly 900 feet of coal measures below the Thick coal containing many thick and excellent coals, but totally different from the beds which are elsewhere to be found below the Thick coal, while in no other part of the coal-field is there a greater thickness below it than 400 or 500 feet at the very outside, the greatest known thickness being 340 feet.

This supposition then would involve still greater changes than are supposed on the other side, besides being opposed to all other species of evidence.

Details of Wyrley and Essington.—It would hardly be worth while to analyse the pit sections of Essington and Wyrley with the minuteness of detail which has been given to those of the central and southern portion of the field, even if we possessed the requisite materials. But as the coals themselves are the only beds of much value, there is little or no mention made of the nature of the substances that lie between them in most of the sections that have been supplied to us.

The ironstone that is considered of most value is one below the Yard coal of Wyrley, which is therefore called the Yard coal ironstone. Mr. Gilpin of Wedges Mills informs me that this resembles the black band of North Staffordshire, but that it varies a good deal in character. In one shaft the measure was 4 feet thick, the top stone being 4 inches, the middle 8 to 12 inches, and the bottom 3 to 5 inches; while in the next shaft there were two layers of top stone, one being very good, with occasional large balls of ½ to ¾ cwt. each. In another adjacent shaft there was in the place of the top stone "merely a white chalky stone, without any iron in it, or a trace of it." There is also another regular measure of ironstone a few feet below this, but it has never been found sufficiently good to work; and with the occasional exceptions mentioned above, and the ironstone immediately above the Bottom or Deep coal, all the ironstones found about Wyrley are very poor in quality.

Mr. Gilpin has lately communicated to me the following section of a pit in the Wyrley field which may be taken as a correct average account of the measures.

		FT.	IN.	FT.	IN.
1.	Above Robins coal	20	0	20	0
2.	Robins Coal			8	0
3.	Fire-clay and batts	14	0	18	0
4.	Ironstone measure	4	0		
5.	Yard Coal — Coal	3	0	5	3
	Fire-clay	1	6		
	Coal	0	9		
6.	Fire-clay	3	0	45	0
7.	Black batts, with two small bands of ironstone and nodules of ditto	4	6		
8.	White clunch	10	6		
9.	Black batts and dark ironstone, very thin in the ground	3	9		
10.	Peldon	1	6		
11.	Dark batts	3	9		
12.	Fire-clay, rock and binds	18	0		

	FT.	IN.	FT.	IN.
13. Charles Coal	-	-	3	0
14. Fire-clay	7	6		
15. Rock binds	5	0		
16. Black batts	0	6		
17. Rough white fire-clay	5	0		
18. Black clod	1	6		
19. White clunch	6	0		
20. Ironstone	0	2		
21. White clunch	2	10	62	6
22. Coal	1	0		
23. Brown fire-clay	6	0		
24. Black clod	1	0		
25. Fire-clay	5	0		
26. Dark clunch	6	0		
27. Binds and rock	3	0		
28. Clod	12	0		
29. Cannel Coal	-	-	4	0
30. Fire-clay	4	6		
31. Dark clunch	7	6		
32. White clunch	19	6		
33. Srong fire-clay	4	0		
34. White clunch	4	0	74	0
35. Soft white fire-clay	3	0		
36. Strong white clunch	12	0		
37. Strong white rock	10	6		
38. Strong white clunch	9	0		
39. Brooch Coal	-	-	3	9
40. Clod	1	6	1	6
41. Benches Coal	-	-	2	3
42. Fire-clay	3	0		
43. Rock and binds	39	0		
44. Measures containing two bands of ironstone 4 inches each, and chance balls of ironstone called the Wyrley Bottom coal stone	4	0	48	0
45. Strong clod	2	0		
46. Wyrley Bottom or Deep Coal	-	-	8	0
			302	9

If to this we add the sinking at Highfields, of which the abstract was given at p. 90, we shall have an accurate idea of the measures passed through in the Wyrley district.

	FT.	IN.	FT.	IN.
47. Dark fire-clay	1	6		
48. Grey fire-clay	2	0		
49. Black batt	0	4		
50. Brown ironstone	0	3		
51. Coal	0	6		
52. Strong binds	4	0		
53. Ironstone	0	2		
54. Dark clod	1	3		
55. Brown ironstone	0	3		
56. Dark clod	1	3		
57. Grey clunch	1	8		
58. Ironstone	0	4	37	0
59. Grey clunch	7	0		

		FT.	IN.	FT.	IN.
60.	Black batt	0	6		
61.	Strong binds	3	0		
62.	Ironstone of inferior quality	0	2		
63.	Strong binds	6	0		
64.	Ironstone of inferior quality	0	3		
65.	Dark clod	2	2		
66.	Ironstone of inferior quality	0	2		
67.	Dark clod	1	11		
68.	Ironstone	0	1		
69.	Dark clod	2	3		
70.	Coal, Bentley Hey, half inferior quality	-	-	3	0
71.	Dark fire-clay	4	0		
72.	Grey fire-clay	4	6		
73.	Strong binds	5	0		
74.	Black batts	0	2		
75.	Black rock	0	6		
76.	Grey fire-clay	1	3	26	0
77.	Grey rock	8	0		
78.	Grey fire-clay	2	0		
79.	Ironstone	0	1		
80.	Dark clunch	0	6		
81.	Coal (? Heathen)	-	-	1	0
82.	Dark fire-clay	0	5		
83.	Dark rock	4	4		
84.	Peldon	1	2		
85.	Dark rock	2	4		
86.	Dark clunch	2	9		
87.	Strong batt	1	4		
88.	Dark clunch	3	0		
89.	Black batt	0	6		
90.	Grey rock	10	0		
91.	Peldon	3	0		
92.	Rock	3	0		
93.	Grey clunch	5	0		
94.	Hard grey rock	9	0		
95.	Strong binds	30	0		
96.	Grey fire-clay	9	0		
97.	Ironstone of inferior quality	0	1		
98.	Dark fire-clay	1	0	132	6
99.	Black batts with one 4 in. ball of ironstone	2	0		
100.	Fire-clay	1	0		
101.	Grey clod	4	0		
102.	Blue binds	5	0		
103.	Dark binds	8	0		
104.	Light rock	3	0		
105.	Dark binds	6	0		
106.	Peldon	1	0		
107.	Clod, supposed to be the New Mine ironstone clod, but not here containing workable ironstone	1	2		
108.	Ironstone	0	2		
109.	Dark clod	3	0		
110.	Ironstone	0	3		
111.	Measures, supposed to be those of the Pennystone ironstone, but not gettable	12	0		

	FT.	IN.	FT.	IN.
112. Coal. Sulphur Coal, the equivalent of the Top or Two-foot coal of the Brown Hills - - - - - -			1	2
113. Fire-clay - - - - -	2	0	2	0
			202	8
Adding the upper part of the section - - -			302	9
We get a total of - - - - - -			505	5

(*See Vertical Sections, sheet* 16, *No.* 3, *and sheet* 26, *No.* 39.)

It will also be advisable to give here in detail the section of Mr. Mills' Engine pit at Essington Wood (communicated by Mr. Becket, and now engraved in Vertical Section sheet No. 26, section No. 38), and follow that with abstracts of some other sections from the neighbourhood of Wyrley.

Section of Mr. Mills's Engine pit at Essington Wood.

	FT.	IN.	FT.	IN.
1. Red clay and sand } Drift 2. Yellow clay - }	12 6	3 0	18	3
3. Blue clay - - -	2	6		
4. Fire-clay - - - -	2	0		
5. Rock - - - - -	11	6		
6. Blue clunch - - - -	3	6		
7. Batt and Coal - - -	2	0		
8. Dark ground - - - -	1	0		
9. Fire-clay - - - -	12	0		
10. Parting - - - -	0	2		
11. Fire-clay with stone (ironstone) -	5	7	69	11
12. Black parting - - -	1	0		
13. Fire-clay - - - -	6	0		
14. Parting - - - -	0	8		
15. Fire-clay - - - -	3	7		
16. Dark ground - - - -	3	0		
17. Fire-clay - - - -	3	0		
18. Black parting - - - -	0	9		
19. Coal - - - - -	1	9		
20. Dark ground with ironstone - -	9	11		
21. Coal - - - - -	2	8		
22. Parting - - - -	0	9		
23. Coal - - - - -	3	0		
24. Parting - - - -	1	0		
25. Coal - - - - -	0	9	12	5
26. Parting - - - -	1	3		
27. Coal - - - - -	0	9		
28. Parting - - - -	1	6		
29. Coal - - - - -	0	9		
30. Dark ground - - - -	3	0		
31. Coal - - - - -	1	2		
32. Fire-clay - - - - -	21	0		
33. Strong clunch, intermixed with peldon	18	9	70	5
34. Strong clunch - - - -	7	0		
35. Dark ground - - - -	2	0		
36. Fire-clay - - - - -	17	6		

		FT.	IN.	FT.	IN.
37.	Coal and batt	-	-	2	1
38.	Fire-clay and batt	6	0		
39.	Clunch	11	0		
40.	Dark binds	6	0	32	6
41.	Clunch	5	6		
42.	Dark clod	4	0		
43.	Coal	3	0		
44.	Parting	0	2	7	6
45.	Coal	4	4		
46.	Strong fire-clay	5	6		
47.	Strong light rock	8	8		
48.	Dark binds with rock	13	5		
49.	Peldon	2	6		
50.	Light binds with rock	9	0		
51.	Strong dark ground	4	0	57	3
52.	Coal	0	10		
53.	Strong dark clod	6	3		
54.	Strong dark clod, intermixed with ironstone	7	1		
55.	Old Robins Coal (of Wyrley) — Coal	1	0	5	8
	Parting	0	2		
	Coal	4	6		
56.	Strong batt	1	8		
57.	Dark clunch	4	0		
58.	Little Coal	0	7		
59.	Fire-clay	0	6		
60.	Strong dark ground, with ironstone	2	11	34	7
61.	Strong mixed ground	3	0		
62.	Grey binds	10	6		
63.	Strong dark clod, with ironstone	3	5		
64.	Strong dark ground	8	0		
65.	Yard Coal (of Wyrley) — Coal	3	0	5	0
	Parting	0	6		
	Coal	1	6		
66.	Fire-clay	1	6		
67.	Light binds	12	6		
68.	Parting	0	4		
69.	Fire-clay	1	8		
70.	Little Coal	0	9		
71.	Fire-clay	7	0		
72.	Grey binds	6	10	49	10
73.	Light rock, with black partings	6	9		
74.	Little Coal	1	3		
75.	Strong fire-clay	6	0		
76.	Light rock	1	3		
77.	Grey binds	3	2		
78.	Dark clod	0	10		
79.	Charles Coal (of Wyrley)	-	-	2	3
80.	Fire-clay	5	0		
81.	Grey binds	5	0	29	8
82.	Light rock	0	10		
83.	Grey binds	18	10		
84.	Cannel Coal (of Wyrley)	-	-	3	9

		FT.	IN.	FT.	IN.
85.	Strong dark ground	6	0		
86.	Peldon	1	0		
87.	Parting	0	8		
88.	Strong dark batt	4	0		
89.	Parting	0	6	57	3
90.	Strong dark batt	6	4		
91.	Light binds	31	9		
92.	Rock	7	0		
93.	Brooch Coal (of Wyrley)	2	2		
94.	Dark ground	3	6	6	3
95.	Coal (? Benches of Wyrley)	0	7		
96.	Light binds	20	5		
97.	Strong rock	7	0		
98.	Coal (not known at Wyrley)	2	0		
99.	Parting	1	3	73	10
100.	Strong light binds	19	2		
101.	Ditto with ironstone	20	3		
102.	Light binds	3	9		
103.	Bottom Coal of Wyrley: Coal	5	6		
	Parting	0	7	8	7
	Coal	2	6		
104.	Various measures	-	-	38	0
105.	Four Foot Coal	-	-	4	0
	(*Vertical Sections, sheet* 26, *No.* 38)			589	0

The following are the abstracts of some other Wyrley sections:—

Section at Longhouse.

	FT.	IN.	FT.	IN.
1. Red sandy rotch, perhaps part of New Red sandstone	35	6	–	
2. Alternations of clunch, grey rock, and black batt	101	0	–	
3. Coal and batt	-	-	1	9
4. Rock and clunch	10	0	–	
5. Coals and partings, principally batts	-	-	5	10
6. Dark clunch	1	11	–	
7. Coal	-	-	2	0
8. Fire-clay, clunch, and rock	74	0	–	
9. Coal (Old Robins coal)	-	-	6	6
10. Various measures	84	0	–	
11. Coal (probably the Charles coal)	-	-	3	0
12. Various measures	54	0	–	
13. Coal (Cannel coal)	-	-	3	6
14. Various measures	81	0	–	
15. Coal (Brooch and Benches)	-	-	7	
16. Various measures	48	0	–	
17. Coal (called Bottom coal)*	-	-	7	0
	489	5	36	7
	36	7		
	526	0		

* In several parts of the Wyrley field there is in the Bottom (or Deep) coal what is known to the colliers as the Middle batt or parting. This is always found, but

*Section of Mr. Gilpin's new pits between Church Bridge and Wyrley Bank.**

			FT.	IN.	FT.	IN.
1.	Clay, shale, &c.		30	0	—	
2.	Robins coal		—	—	8	0
3.	Black batts, with ironstone balls		22	0	—	
4.	Yard coal		—	—	3	0
5.	Fire-clay, batt, and binds		69	0	—	
6.	Charles coal		—	—	3	0
7.	Binds and rock		64	0	—	
8.	Cannel coal		—	—	4	0
9.	Binds, &c.		84	0	—	
10.	Brooch coal		—	—	4	0
	Rubbish } 7 3		1	0	—	
11.	Benches coal		—	—	2	3
12.	Binds, &c.		40	0	—	
13.	Bottom coal		—	—	8	0
14.	Binds, &c.		39	0	—	
15.	Another coal		—	—	3	0
			349	0	35	3
			35	3		
			384	3		

Section of Mr. Gilpin's pits near the Cock public-house.

				FT.	IN.	FT.	IN.
1.	Soil and clay			13	6	—	
2.	Clunch and batt, with ironstone			6	7	—	
3.	Old man's coal = Yard coal			—	—	3	9
4.	Fire-clay, batt, and clunch, with grubb ironstone	19	6	35	6	—	
5.	Flying coal	1	0				
6.	Fire-clay, binds, &c.	15	0				
7.	Charles coal			—	—	2	4
8.	Fire-clay and clunch	15	6	54	0		
9.	Flying coal	3	0				
10.	Fire-clay, binds, and clunch	35	6				
11.	Cannel coal			—	—	3	11
				109	7	10	0
				10	0		
				119	7		

varies in thickness in different pits from 18 to 21 inches, undulating considerably in short distances. In one pit this batt is represented by a very hard rock four inches in thickness, very fine in the grain, and of a greyish white colour.—*Note by Mr. Gilpin.*

* Given me by Mr. Gilpin, and Jesse Potts, his ground bailiff.

*Section at Mr. Yates' colliery at Wyrley.**

					FT.	IN.	FT.	IN.
1. Soil and gravel	-	-	-	-	12	0		
2. Clunch and binds	-	-	12	0				
3. Flying coal	-	-	1	0	35	6		
4. Fire-clay and rock	-	-	22	6				
5. Charles coal	-	-	-	-	-	-	3	0
6. Fire-clay and clunch	-	-	12	0				
7. Flying coal	-	-	1	6	40	9		
8. Fire-clay, binds, and rock		-	27	3				
Cannel coal	-	-	-	-	-	-	3	8
					88	3	6	8
					6	8		
					94	11		

Relation of the Coals, &c. of Wyrley and Essington to the Red coal-measure clays.—We might look upon the red measures in the upper part of the Longhouse section as being the bottom of the Red clays of the coal-measures, if it were not for the fact that they come in at a height of only 168 feet above the Old Robins coal, while in the Essington colliery there is a thickness of 252 feet of true coal-measures over that coal, with beds of coal and clunch and fire-clay throughout, and without the appearance of any red clays except those which are undoubtedly superficial or drift materials. It is probable then that the red beds at Longhouse belonged to the New red sandstone, and that the shaft was sunk through the boundary fault which inclined obliquely across it.

We have, therefore, here no means of determining exactly the height above the Old Robins or other of the Wyrley and Essington coals at which the Red coal-measure beds ought to make their appearance in the section. But as the beds in the Essington colliery dip at a gentle angle in the direction of the south-west extension of the Red clays in the Essington Wood brick pits, it is probable that the uppermost beds of Essington colliery would be covered by the Red clays about half way between the two places, and without any very large increase of thickness, not more, perhaps, than 100 feet or thereabouts.

If this be true, the Essington and Wyrley coals may be expected to lie at no very unreasonable depth beneath the Red clays of the Essington Wood brick pits, and over all the space up to the boundary fault as drawn in the latest edition of our maps (that of 1859).

The Red coal-measure clays, however, are worked on the eastern side of the district about Walsall Wood as well as on the west side near Essington, and have beneath them coals which are now being worked. Let us therefore examine,

The relations between the Red coal-measure clays of Walsall Wood and the Coal-measures of Coppy Hall Colliery and the Aldridge Trial Pit.—The Red clays about Walsall Wood and the neighbourhood have long been extensively opened by brick pits. Their general dip is northerly at very slight angles, not more than 3°. A shaft has now been lately sunk through a considerable thickness of these clays south of all the brick pits, and where, therefore, they are probably thinner than

* The two latter sections were given me by Mr. George, of Bentley.

at any locality further north. It was undertaken by the Rev. Baily Williams, whose enterprise has been deservedly rewarded by the discovery of several good coals and some ironstone below them. This pit is called No. 1. of the Coppy Hall colliery, and is situated just over the "o" of "Stubbock's Green," as engraved on the Ordnance map. The following is an abstract of the measures passed through, communicated by Mr. Roberts, the mine agent, of Walsall :—

Section of Coppy Hall Colliery.

		FT.	IN.	FT.	IN.
1.	Red clay and marl, &c. - -	218	0	–	
2.	Green and red shales interstratified with dark grey and black measures -	37	0	–	
3.	Coal - - - - -		-	1	0
4.	Fire-clay, binds, &c., with one or two small coals - - -	140	6	–	
5.	Coal, four small coals with partings -		-	12	8
6.	Fire-clay, binds, &c. with ironstone balls	92	8	–	
7.	Coal, with batt - - - -		-	2	3
8.	Binds, with ironstone, rock, &c. -	33	7	–	
9.	Coal - - - - -		-	7	6
10.	Binds, with ironstone - - -	11	0	–	
11.	Coal - - - - -		-	1	0
12.	Binds, with ironstone, &c. - -	12	10	–	
13.	Coal - - - - -		-	4	0
14.	Shales and binds, with ironstone -	18	0	–	
		562	7	28	5
		28	5		
		591	0		

(*See Vertical Sections, sheet* 26, *No.* 44.)

There was a trial pit sunk about ten years ago, a little more than a mile to the southward of the Coppy Hall colliery, a little north of the Red House near Aldridge. As the measures hereabouts all dip to the north, or a little east of north, at an angle of 30°, the beds, which lie deep at Coppy Hall colliery ought, if there be no fault between the two places and the increase of dip take place gradually, to crop out at or about the Aldridge trial pit.

The following is an abstract of the section of that pit, which was published by Mr. Roberts in the year 1849 :—

Abstract of the Measures passed through in the Aldridge Trial Pit.

		FT.	IN.	FT.	IN.
1.	Upper measures - - -	55	0	–	
2.	Coal and batt - - - -		-	2	9
3.	Fire-clay and clod - - -	18	3	–	
4.	Coal and batt - - - -		-	1	9
5.	Fire-clay, clod, and binds - -	10	9	–	
6.	Coal and batt - - - -		-	4	6
7.	Fire-clay, binds, &c. - - -	86	6	–	
8.	Coal and batt - - - -		-	3	6
9.	Fire clay, &c., with small ironstone -	31	7	–	
10.	Coal with parting - - -		-	7	8

		FT.	IN.	FT.	IN.
11.	Fire-clay, binds, with good ironstone, &c.	18	6	–	
12.	Coal		–	1	0
13.	Ironstone measures, fire-clay, &c.	17	4	–	
14.	Coal		–	5	10
15.	Fire-clay, rock, and binds, with ironstone, &c.	61	4	–	
16.	Coal		–	6	6
17.	Fire-clay	2	9	–	
18.	Coal		–	1	0
19.	Fire-clay, clod, &c.	16	8	–	
20.	Coal		–	3	4
21.	Various measures	77	9	–	
		399	5	37	10
		37	10		
	Total	437	3		

(*See Vertical Sections, sheet* 16, *No.* 4.)

It would be very unsafe to draw conclusions from a mere resemblance in the thicknesses and grouping of beds in two sections more than a mile apart, but looking both to the fact of the occurrence of ironstone, and the near agreement in thickness, it seems very probable that the bed numbered 13 in the Coppy Hall section, is the same as that numbered 14 in the Aldridge trial pits. The resemblance is very striking, if we place side by side the following parts of the two sections:—

	Coppy Hall.		Aldridge.	
	No.	Thickness.	No.	Thickness.
		FT. IN.		FT. IN.
Fireclay, Binds, &c.	6	92 8	7	86 6
Coal with batt	7	2 3	8	3 6
Binds and fire-clay with ironstone	8	33 7	9	31 7
Coal	9	7 6	10	7 8
Binds and fire-clay with ironstone	10	11 0	11	18 6
Coal	11	1 0	12	1 0
Binds, &c. and ironstone measures	12	12 10	13	17 4
Coal	13	4 0	14	5 10

Over No. 6 in the Coppy Hall shaft there are several coals and batts with partings, while over No. 7 of Aldridge there are likewise some small coals and bats, separated, however, not by mere partings, but by groups of beds, though not of large thickness, these being surmounted by 55 feet of various measures, which may very well be the lower part of the 140 feet of measures grouped as No. 4 in the Coppy Hall colliery. In this case the beds which reached the surface at the Aldridge shaft would be about 340 feet deep at the Coppy Hall colliery.

If we might be permitted to extend our comparison from the eastern to the western side of the coal-field, and to suppose that the small coals and batts which are numbered 2 to 6 inclusive in the Aldridge section, and those marked No. 5 in the Coppy Hall section were the same group, there or thereabouts, as the group of small coals and partings numbered as No. 20 to 29 in the Essington section, given at page 94, we should

find a very great resemblance in the thicknesses of the beds immediately below them, as follows :—

	Aldridge.	Coppy Hall.	Essington.
1. Small coals and partings -	38 0	12 8	12 5
Intermediate -	86 6	92 8	70 5
2. Coal and batt -	3 6	2 3	2 1
Intermediate -	33 7	31 7	32 6
3. Coal and partings	7 8	7 6	7 6
Intermediate -	36 10	24 0	57 3
4. Coal and partings	5 10	4 0	5 8

If the above be anything more than an accidental coincidence, and we may really believe that the measures are the same beds in the three places, it would then follow that, as the fourth or lowest coal just mentioned at Essington is the Old Robins coal, the coal No. 13 of Coppy Hall, and that No. 14 of Aldridge is also the same as the Old Robins coal of Wyrley. Mr. Gilpin, of Wyrley, on the other hand, is of opinion that the ironstones over coal No. 16 of Aldridge and below coal No. 13 of the Coppy Hall section are the same ironstones as those just above the Bottom coal of Wyrley. If that be so, then coal No. 16 of the Aldridge section, p. 100, is the Bottom coal of Wyrley, No. 20 probably the Bentley Hey coal, No. 14 probably the Wyrley Brooch and Benches, No. 10 the Cannel, No. 8 the Charles, and No. 6 the Yard coal. In the Coppy Hall pit then, No. 13 must be the Brooch and Benches, No. 11 the Cannel, No. 9 the Charles, No. 7 the Yard, and No. 5 the Old Robins. If this be so, there is a very wide discrepancy in the thickness of the measures in the two sides of the coal-field, and a still greater one in the thickness between the base of the red clays and the Old Robins coal. If No. 5 of the Coppy Hall pit represent the Old Robins of Essington, we have only about 180 feet between it and the red clays there, while at Essington there is 252 feet without the appearance of any red clays, and they are probably at least 30 or 40 feet higher, perhaps 100 feet. Whatever may be the value of these identifications of particular beds, we may feel pretty sure that the beds at Coppy Hall and the Aldridge trial pits are on about the same geological horizon as the upper coals of Essington and Wyrley, and that all the other Wyrley coals will probably be found eventually below them, as well as the Brown Hills and Pelsall beds at a still lower depth.

If this comparison of the measures on the two sides of the coal-field be right, it follows that as the coal No. 13 of the Coppy Hall colliery lies at a depth of about 280 feet below the base of the red clays there, that is the probable position at which the Old Robins coal may lie below them at Essington Wood, and that as in the pits, of which the section is given at p. 94, it is 252 feet deep, if that pit had been sunk a little farther on the dip of the beds, the Red coal-measure clays would have appeared in the top of it.

A further consequence of this hypothesis would be that as the place of the Deep coal of Pelsall and the Brown Hills is about 650 feet below the Old Robins coal of Wyrley, it is also about that much under the coal No. 13 of Coppy Hall and No. 14 of Aldridge, and must, therefore, be about 1,200 feet below the surface at Coppy Hall; we should hence get a rough measure for the amount of the fault, which brings in the upper red coal-measure clays of Walsall Wood to the eastward of the outcrop of the Deep coal on Pelsall Heath, for it is obvious that it must have a downthrow to the eastward of considerably more than 1,000 feet.

It is by no means wished to put forward these statements of figures as absolutely trustworthy or exact, still a fault which brings in those

Upper Red clays that lie above all the workable coal-seams of the field and are apparently the same as those which are known to lie 100 yards above the Thick coal, and places these Upper clays on a level and in close juxtaposition with the very base of the coal-field must have a throw of something about that amount. That these Upper Red beds are in reality upper Coal-measures is confirmed by all the beds being apparently quite conformable to each other, and the black and red measures graduating into each other at the Coppy Hall colliery.

It would follow from this that workable beds of coal lie at no inaccessible depth over all the corner of ground about Walsall Wood and Clayhanger, and may be reached after passing through from 300 to 600 feet of the red clays.

The same will be true also for the red brick clays of Essington Wood and the strip of country north and south of it, where these clays prevail; as also for the red clays of Rumour Hill east of Cannock and those of Littleworth near Hednesford, although near Cannock it is probable, from Mr. Gilpin's account, that the ground is too much cut up by faults to make exploration other than very hazardous.

The Cannock Chase District.—It has been already stated that the dip of the measures all across the part of the coal-field now being treated of is from east to west. In the northern part of the Brown Hills field, however, the beds are beginning slightly to curve round, so as to strike to the north-east and dip to the north-west. It is probable then that the beds all across the field will follow this curve, and that the Wyrley coals will curve round from Church Bridge and strike towards the north-west in the direction of Brereton.

This probability is confirmed by the fact of two outcrops of coal being still traceable in Cannock Chace by means of some old workings having this bearing. The one outcrop runs from about Heathy Hays to near Cooper's Lodge, as was formerly observed by myself. Another was traced by the persons employed by the Commissioners who divided the mines of Norton Manor. Mr. Beckett, of Wolverhampton, who was associated with these persons, has allowed me to examine the plans and reports which were drawn up.* This outcrop runs from a little north of Norton Church on to Norton Common, and it is stated in the report above alluded to that it was the opinion of the reporters that this coal was the same as the Bentley Hey coal, or that four-foot coal which lies next below the Wyrley (so called) Bottom coal.

We may perhaps be justified in looking on this outcrop at Norton as more probably that of the Eight-foot or Wyrley Bottom coal itself, and that the Bentley Hey coal crop will be found still further to the south-east, especially when we remember the existence both of the Bentley Hey coal and the Heathen coal in the pit of the Cathedral colliery, which lies in the trough of the Rising Sun 2 miles to the south-east.

Now, with the lower coals undoubtedly at the Brown Hills, the upper coals a little south of Cannock, and these traces of the middle beds half way between, we may feel pretty sure that we should have the whole workable and valuable part of the coal-field cropping out in regular succession from west to east along the line of Watling Street between the two boundary faults. The distance along the ground is about 4½ miles, say 24,000 feet, and the total thickness of the measures as presumed from the section given at p. 23, will be about 1,000 feet. This will give a mean inclination of about 1 in 24 or not quite 3°, which

* It was from this detailed survey that the information was gained that enabled Professor Ramsay to introduce into the map the faults in the neighbourhood of Norton reservoir, and correct some of my former work which was based upon imperfect and often erroneous information.

agrees very closely with the observed inclination in all the workings of the mines.

It is then highly probable that the whole of the Coal-measures will sweep pretty steadily across Cannoek Chase up to Brereton.

Old shallow workings have been carried on here and there about Cannock Chase, of which the following records were formerly gained and published in the first edition of this Memoir.

At Cannock mill, just east of Cannock, there were some coal-pits a few years back worked by Lord Hatherton, and called the Rumour Hill pits, of which I got the following section from the recollection of Abraham Ward, well-sinker, at Cannock :—

	FT.	IN.	FT.	IN.
1. Red marl	6	0	–	
2. White binds	12	0	–	
3. Cannel coal	–	–	3	6
4. Bind measures	24	0	–	
5. Rock	3	0	–	
6. Two-foot coal	–	–	2	0
7. Binds, rock binds, clunch, &c.	72	0	–	
8. Coal	–	–	4	6
9. Measures	90	0	–	
10. Stinking coal	–	–	5	0
	207	0	15	0
	15	0		
	222	0		

We cannot with any degree of certainty identify any of these beds with any of those at Wyrley, but Mr. Gilpin believes them to belong to the upper Coal-measures of Wyrley.

Just south of the hamlet of Hednesford there are some old coal workings, of which I got the following section from W. Haycock, an old collier at Brereton :—

	FT.	IN.	FT.	IN.
1. Gravel	20	0	–	
2. Clod	12	0	–	
3. Yellow rock	42	0	–	
4. Clod	10	0	–	
5. Coal	–	–	7	0
6. Clod containing good ironstone	90	0	–	
7. Coal	–	–	4	0
	185	0	11	0
	11	0		
	185	0		

Some new shafts were being sunk by Mr. Piggott just to the eastward of Hednesford, in the year 1858, in which they had found what they believed to be the Wyrley Bottom or Eight-foot coal at a depth of 300 feet. It was there only 6 foot thick, and 60 feet below it there was a Four-foot coal, which might possibly be the Bentley Hey coal, while 90 feet over it, or at a depth of 210 feet from the surface, there was another coal of 4½ feet thick, believed to be the Wyrley Cannel coal. They had also got the black nodular ironstone full of tubular cavities, from which at Wyrley it is called the Grub ironstone.

On the authority of W. Haycock, the measures at the old Botany Bay colliery, just north-west of Hednesford Pool, were,—

	FT.	FT.
1. Running sand	51	–
2. Clod	29	–
3. Coal	–	5
4. Clod	20	–
5. Coal	–	3
	180	8
	8	
	188	

The same person also gave me the following scraps of information:—

Section between Heathy Heys, Wimblebury, and Cooper's Lodge.

	FT.	IN.
1. Gravel	12	0
2. Clod	90	0
3. Cannel coal	1	4
4. Clod	6	0
5. Coal	4	0
	113	4

Section between Sugars Lodge and Lodge Barn in Beaudesert Old Park.

	FT.	IN.
1. Waterclay	6	0
2. Clod	60	0
3. Coal	5	0
Under which they bored down through many measures containing 9 coals	360	0
	431	0

He also told me that, at Noddyfield, near Mr. Cocking's house, there was the same section as at Hednesford, the seven-foot coal being 51 feet deep at Noddyfield, instead of 84, as at Hednesford. As Noddyfield is much higher ground than Hednesford, there must, if this information be correct, probably be a gentle westerly or north-westerly dip over all the intervening space.

I procured an old section from the late Mr. Figgins, of Brereton Heys, mine agent to the Marquis of Anglesea, which was taken either at Noddyfield, or in the Old Park of Beaudesert, most probably the former. In either case it does not go greatly against W. Haycock's evidence, and in the latter tends to confirm it.

The following is an abstract of this section :—

	FT.	IN.	FT.	IN.
1. From surface to the bottom of a coal of which the thickness is not stated	90	0	–	
2. Clunch, binds, fire-clay, rocks, &c., with three little nine-inch or foot coals intervening	70	6	–	
3. Coal	–		4	0
4. Rock, binds, &c.	25	6	–	
5. Coal	–		2	0
6. Fire-clay, binds, rock, clunch, &c.	39	0	–	
7. Coal	–		4	0
8. Fire-clay	0	0	–	
	225	0	10	0
	10	0		
	235	0		

This section evidently passes through the same measures as those which are now being worked near Brereton, about three miles to the northward.

The Brereton Collieries.—Of the pits in the Brereton colliery district I have had sections supplied to me by Mr. George, of Bentley; Mr. Vernon Poole, of Brereton, Lord Talbot's agent; and by the late Mr. Figgins. These sections are so nearly identical that they seem all to have come from the same source, and to apply equally to all the Brereton district. The section now engraved in Vertical Sections, Sheet 16, No. 1, will give the details, but I add here an abstract:—

Brereton Section.

		FT.	IN.	FT.	IN.
1.	Red and white gravel (part of the New red sandstone conglomerate) - -	80	0	–	
2.	Red and yellow marl, rock, clod, and batt	16	6	–	
3.	First coal - - - -	-		4	6
4.	Clod with ironstone - - -	19	10	–	
5.	Second coal - - - -	-		2	6
6.	Clod and rock - - - -	51	3	–	
7.	Third coal - - - -	-		2	0
8.	Fire-clay and clod - - -	13	0	–	
9.	Fourth coal - - - -	-		4	0
10.	Rock clod and ironstone - -	30	1	–	
11.	Fifth coal - - - -	-		4	0
12.	Fire-clay - - - -	3	0	–	
13.	Sixth coal - - - -	-		0	4
14.	Rock with ironstone - - -	14	8	–	
15.	Seventh coal - - - -	-		2	3
16.	Rock with ironstone, and clod and batt	36	0	–	
17.	Eighth coal - - - -	-		4	0
18.	Batt, clod, and light rock and clod -	50	0	–	
19.	Ninth coal - - - -	-		0	6
20.	Clod, &c. - - - -	6	0	–	
21.	Tenth coal - - - -	-		3	3
22.	Rock - - - - -	13	4	–	
23.	Eleventh coal - - - -	-		1	0
24.	Clod, rock, and ironstone, &c. - -	22	10	–	
25.	Twelfth coal - - - -	-		9	0
26.	Rock, binds, and ironstone - -	48	7	–	
27.	Coal, not enumerated - - -	-		2	0
28.	Binds with ironstone - - -	21	7	–	
29.	Thirteenth coal - - - -	-		5	0
30.	Fire clay and clod - - -	24	0	–	
31.	Fourteenth coal - - - -	-		1	0
32.	Rock, clod, and ironstone - -	105	8	–	
33.	Fifteenth coal - - - -	-		4	3
		556	4	49	7
		49	7		
		605	11		

(*See Vertical Sections, sheet* 16, *No.* 1.)

Below the fifteenth coal they sank some distance in red measures.

It will be at once seen from the inspection of this section that it is not possible, from the mere thickness and relative position of its beds, to

discover any relation between it and any of those we have examined in the southern part of the field. Everything, however, seems to confirm the conclusion formerly arrived at, that, speaking generally, the Brereton coals are the same as the Wyrley coals, a little more split up and separated from each other. It is remarkable, too, that the total amount of the Brereton coals, when added together, namely, 49 feet, is nearly the same with their total amount at Wyrley, namely, 46 feet.*

The Lickey Coal-measures.—Before closing the account of the Coal-measures it is necessary just to mention two little outlying districts of that formation on the south of the field,—one is near the Lickey Hill, where small patches of Coal-measures with one or two little bands of coal were found on each side of the quartz ridge, near the New Rose and Crown.

The Stonehouse Coal-measures.—Another is near the Stone House, south-west of Harborne. At this latter locality Mr. Flavell sank 240 feet through true Coal-measures, grey shales, with nodules of ironstone, but without traversing any bed of coal. It is obviously impossible to say what part of the general series of Coal-measures those found at these two localities belong to.

CHAPTER VII.

Description of the Rocks—*continued.*

5. *The Silurian Rocks.*

Of the Silurian formation we have, in or near the South Staffordshire coal-field, parts of three different subdivisions:—

1st. A portion of the Ludlow rocks containing a band of limestone, believed to be the same as the Aymestry limestone.

2nd. The Wenlock and Dudley rocks entire.

3rd. A portion of the Llandovery (formerly considered part of the Caradoc) sandstone.

These rocks have been so fully described by Sir R. I. Murchison in his "Silurian System" that there remains but little to say respecting them.

Ludlow and Sedgley rocks.—The mass of the Ludlow and Wenlock rocks, or, as they might here be called, the Sedgley and Dudley rocks, consists of a brown or blueish grey argillaceous shale, always very smooth and compact, thick-bedded and regularly jointed. In the upper portion is a band of dark brown nodular and concretionary limestone, some 20 or 25 feet in thickness. It is locally called the "Brown lime." From its containing the *Pentamerus Knightii*, and other fossils, and from its position, it is with great probability identified with the Aymestry limestone. This limestone shows itself at Sedgley, at Turner's

* Near Dudley, the total amount of all the coals would be about 57 feet. The richest part of the field in amount of coal-beds, both absolutely and still more in proportion to the whole thickness of the measures in which they lie is between Wolverhampton and Bilston, where the lower coals are becoming rapidly thicker, and the Thick coal is still nearly unbroken and undiminished. The total amount of the coals in a vertical section there would in some places be upwards of 70 feet, all within a depth of about 300 feet from the surface.

Hill, and at the Hayes near the Lye Waste, 2 miles east of Stourbridge.

At a certain depth below this, is the Wenlock and Dudley limestone, which is locally called "White lime."

What is the exact thickness intermediate between these two limestones, or how far they were vertically apart at their period of deposition, we have no means of determining. In the only place where they both crop to the surface in one area, namely, at Sedgley Beacon and Hurst Hill, a fault runs between the two which has been traced on one side in the workings, but without arriving at any means of determining the amount of its "throw." I have, however, assumed 800 or 1,000 feet as the vertical distance between the limestones. This thickness enabled me to draw the sections, with the least amount of dislocation and disturbance, of which there was no decided evidence; but I feel by no means confident that that thickness ought not to be either diminished or increased.

There is no lithological distinction between the shale or bavin above the Dudley limestone and that below it, but the one above is assumed to belong to the Ludlow group, and that below it to the Wenlock.

Wenlock and Dudley rocks.—The Wenlock and Dudley limestone forms two bands of solid concretionary and flaggy limestone, with many calcareous nodules, concretions, and small flaggy beds, both between, above, and below them.

At Dudley, we have the two following sections of the limestone given in the Silurian System:—

The Castle Hill.	FT.	IN.
Upper limestone or thin measures	23	1
Intermediate shale	–	
Lower limestone or thick measures	35	7

The Wren's Nest.	FT.	IN.
Upper limestone	28	4
Intermediate shale	90	0
Lower limestone	42	3

At Hurst Hill, the beds are collectively thinner and the limestones closer together. At Mr. Bagnall's limestone pits at Dudley Port they found two bands of limestone,—upper, 27, and lower, 24 feet thick,—resting directly one on the other. At Mr. Giles's pit, however, according to Sir R. I. Murchison, the limestone worked was 21 feet thick, and they reached, by boring, another mass of limestone 150 feet below it. At Deepfield's, a little east of Hurst Hill, according to "Smith's Miner's Guide," they sank below the Coal-measures through 150 feet of blue rocky clunch, probably Silurian shale, and then came on limestone in about ten beds of nearly 3 feet each.

In the neighbourhood of Walsall the Dudley and Wenlock limestone consists of—

	FT.
Thin or upper limestone	12
Intermediate shale, &c.	120
Thick or lower limestone	34

The following more detailed section of these beds has been furnished by Mr. Beckett, of Wolverhampton, who procured it from Mr. B. R. Smith, of Walsall:—

				FT.	IN.	FT.	IN.
1.	Surface matter, Diamonds ironstone grit rock, and Flying reed limestone binds			61	4	–	
2.	The Four-yard stone, first thick band of limestone					12	0
3.	Mush, clunch, &c.			108	6	–	
4.	Covering Burr, not gettable	1	6				
5.	Burr	1	8				
6.	Thick Burr	3	3				
7.	Chattering Burr	1	0				
8.	Chippers	3	3				
9.	Captain	1	0				
10.	Seven floors	1	8				
11.	Fourth shot	1	6	Thick limestone		34	2
12.	Third shot	1	0				
13.	Strong stone	3	0				
14.	Yellow clay floor	0	10				
15.	Flints	2	9				
16.	Half yard measure	1	6				
17.	Bell flag	2	3				
18.	Knotty floor	2	0				
19.	Thick floor	3	8				
20.	Rottens	2	4				
21.	Clunch			8	0	–	
				177	10	46	2
				46	2		
	Total			224	0		

At Hobbs Hole, a little east of Darlaston, the Silurian rocks lying below the Coal-measures have the following composition, according to the information of Mr. Smallman:—

	FT.	IN.	FT.	IN.
From surface to bottom of Heathen coal	15	0	–	
From that to bottom of Coal-measures	292	6	–	
	307	6		
Limestone shale			60	0
THIN LIMESTONE			16	6
Limestone shale			90	0
THICK LIMESTONE			30	0
	307	6	196	6

In this neighbourhood (Walsall) the Dudley limestone crops out at a gentle angle, and the lower shale rises from underneath it, spreading out to the east over a tract nearly 2 miles in width, till another band, known as the Barr limestone, rises to the surface at Hay Head, near Great Barr. There is but little to be seen in

the space between those two limestones, but where seen, as in the cutting of the new canal that runs from Hay Head to the Tame Valley, the shale was always found in a nearly horizontal position.

At the Hay Head quarries the Barr limestone rises from beneath the shale at an angle of about 8° or 10° on an average. Drawing the section from these data, the Barr limestone will probably lie at a depth of about 500 or 600 feet below the Dudley limestone, though it may easily be more.

In mineral character, the Barr limestone much resembles that of Woolhope* in Herefordshire, which lies at the junction of the Wenlock and Llandovery rocks, and it may very easily be at or near the actual base of the Wenlock rocks as they exist in Staffordshire. In this case we ought to have the Llandovery sandstone rising out immediately to the east of the Barr limestone.

In the former edition of this Memoir I stated that there was no appearance of this sandstone from underneath the Barr limestone, or below the base of the Wenlock rocks, in the neighbourhood of Great Barr or Hay Head, as I thought I had examined every place where it could appear and had not found it.

The late Mr. Daniel Sharpe, however, called my attention to a quarry of it, which had escaped my notice, in consequence of its small size, and its being situated under a steep bank, overgrown with brambles and nettles, at the side of a field in which, when I visited it, the wheat was high and in full ear.

Llandovery sandstone.—I revisited the locality in the year 1853 and was guided to the old quarry by Mr. George Eglinton, of Shustoke Lodge, who had himself pointed out the quarry to Mr. Sharpe.

In the ploughed field, which slopes gently up to the quarry, fragments of grey shale were observable on the ground with small cakes and concretionary flakes of limestone, like those described below as being found at the Colmers, near the Lickey.

It is probable that these are the representatives of the Barr limestone, which is very likely of partial occurrence, as an actual limestone, though thin calcareous courses may be found generally on its horizon. At the upper end of the field, under the hedge, was the small quarry. There was but a very small exposure of rock, not enough to show the dip of the beds, which, however, may be presumed to be the same as that of the other Silurian rocks of the neighbourhood, or about 5° to the west. The rock was a pale yellow or brown sandstone, in some places nearly white and purely quartzose, in others stained with ferruginous bands forming concentric rings. Other portions were calcareous, almost deserving the name of an arenaceous limestone. It was greatly jointed, splitting into sharp angular fragments.

Some parts of it were highly fossiliferous, and Mr. Salter determined the following species in the few blocks of the rock

* I state this on the authority of Professor Ramsay, who, on one occasion, accompanied me to Hay Head, and who was perfectly acquainted with the limestone of Woolhope, a district I never had the good fortune to visit.

I was able to carry away;* one or two more were brought by other observers.

Fossils in the Llandovery Sandstone, south-east of Shustoke Lodge.

Trilobites.

Encrinurus punctatus - - - -	4
Phacops caudatus - - - - -	1
„ *Stokesii* - - - - -	1
„ *truncato-caudatus?* - - -	1

Mollusca.

Chonetes lata? (probably only a *Leptæna*) -	1
Strophomena compressa - - - -	2
Atrypa reticularis - - - - -	6
Rhynchonella, 2 plaited sp. - - -	8
„ *Wilsoni* - - - -	20
„ small smooth species - -	50
Pentamerus liratus and *P. lens* - - -	2
Pterinea - - - - - -	1
Acroculia Haliotis - - - -	1

Crinoidea.

Periechocrinus moniliformis? stem joints -	30

Bryozoa and Corals.

Fenestella (with close meshes) - - -	1
Favosites alveolaris.	
Petraia bina.	

Mr. Eglinton also showed me just at the back of the house called Daffodilly at Hay Head, in a little deep ditch or gully overgrown with brambles, some beds of exactly similar sandstone, in which, however, we could find no fossils.

This was overlaid to the west, or in the direction of the old quarries of the Barr limestone, by Coal-measure shale containing a small two-foot coal, and cut off to the east by the Permian red marls, &c. North and north-east of it also Coal-measures containing small beds of coal had been found.

These Coal-measures, no doubt, rest unconformably on the upturned and denuded edges of the Silurian rocks, and it is quite possible that the Llandovery sandstone would be found under the greater part of those Coal-measures which spread over the space north-east of the Three Crowns Inn, between the outcrop of the Barr limestone and the Permian rocks which come in on the east side of the Boundary fault.

In the Lower Lickey Hills, between Birmingham and Bromsgrove, there is a ridge of quartz rock determined by Sir R. I. Murchison to be altered sandstone of this age. I can add little to the full and accurate description of this rock and neighbourhood

* See Journal Geol. Soc., Lond., vol. ix. p. 181, April 1853.

which is given in the "Silurian System," and shall, therefore content myself with the following quotations from it:—

"On first examining the tract in 1834, I observed, that at two points on its eastern and south-eastern flank (Colmers and Kendal End) the quartz rock was overlaid by a limestone and shale which contained some corals and shells of the Wenlock formation. At Kendal End, the solid limestone extracted, 23 years before, did not exceed a yard in thickness, but it was accompanied by small concretions called 'batch cakes.' The existence of another thin band of limestone was ascertained by sinking for coal at the Colmers." * * * "The sheds of coal and shale" * * * "were easily penetrated; and the sinkings were continued through a thin layer of impure limestone, only 13 inches thick, which, from its appearance and organic remains, I consider to be one of those calcareous courses which underlie the Wenlock shale, and form the top of the Caradoc ('Llandovery') sandstone (Woolhope limestone)." * * * "After penetrating this limestone, the coal speculators sunk till they were stopped by a hard quartzose sandstone and reddish slaty clay, similar to that which rises on the eastern flank of the quartz hills. Near the southern extremity of Snead's Heath, the cutting of a new road exposed a reddish siliceous sandstone, made up of rounded grains of quartz, containing casts of characteristic Caradoc ('Llandovery') fossils. These fossiliferous sandstones, having in themselves a half-fused appearance, form the upper portion of the true quartz rock of these hills, into which they graduate insensibly at Snead's Heath, so that it is impracticable to draw any defined line between the reddish fossiliferous sandstone and the quartz rock."

The little fragments of limestone or calcareous flags lying on the old spoil banks in the Long Wood near the Colmers, when I examined the ground, were precisely similar to those which I afterwards saw in the ploughed field at Shustoke Lodge. I have, therefore, now no doubt that those calcareous courses at the Colmers, as well as the band of limestone formerly worked at Kendal End at the south end of the Lower Lickey range are also the representatives of the Barr limestone, and that the shales in which they lie repose directly on the Llandovery sandstone. Sir R. I. Murchison, indeed, expressly says above, that after penetrating the limestone bands at the Colmers, the speculators were stopped by hard quartzose sandstone and slatey clay similar to that which rises near the eastern flank of the Quartz Hills (see Fig. 21).

The beds of quartz rock in the Lower Lickey range are tilted at high angles, and in some places much contorted, and the whole must have a thickness of 300 or 400 feet at least.

What influence it was that converted the rather soft sandstone that is to be seen at Barr into hard quartz rock at the Lickey we cannot exactly say, but as the quartz rock has apparently no other cement than a siliceous one, it seems impossible that dry heat could have effected it. If, moreover, there had been heat of a sufficient intensity to cause this alteration, it seems scarcely possible to conceive that the Wenlock shales and limestones should not have been equally effected.

We may, perhaps, be permitted to speculate on the possibility of hot springs having at some period burst out along the line of the Lower Lickey, the water having either itself contained silica in

solution, or having dissolved some of the silica of the sandstone and thus eventually cemented the grains together.

Note on the fossils; by J. W. Salter, Esq.

No traces of true Lower Silurian fossils occur in the district.

1. The fossils of the Bromsgrove Lickey have already been adverted to. It is sufficient to note that they are the common Llandovery or May Hill shells, such as *Pentamerus oblongus*, with *P. lens*, *Spirifer elevatus*, and a variety of *Orthis calligramma*, &c. They occur always as casts in the incoherent red grit, and are generally of full size. The fossils of the small patch of sandstone visible at Shustoke Lodge, near Barr, are also clearly referrible to the Upper Llandovery (or May Hill) zone. Among a number of Upper Silurian forms, such as the common species—

Phacops caudatus,	*Acroculia Haliotis*,
P. Stokesii,	*Periechocrinus moniliformis*,
Atrypa reticularis,	*Favosites alveolaris*, and
Rhynchonella Wilsoni,	*Petraia bina*,

we have the characteristic shell *Pentamerus lens*, a species never known to range out of the Llandovery rocks (*P. liratus* does rise into the Woolhope shales). This shell, with other fossils, was found here in plenty by Mr. J. E. Davis, after Mr. Sharpe had discovered the locality.

2. Woolhope Limestone.

The limestone of Hay Head, near Barr, has been generally regarded, from its position, as the equivalent of the Woolhope band, but there is not much palæontological evidence to prove this, except the occurrence of very large specimens of the *Illænus* (*Bumastus*) *Barriensis*, for which well-known fossil it is the original locality.*

The following are found either there, at Ginity Graves, or at Daffodilly, on the same band :—

Calymene Blumenbachii; Phacops caudatus;
Strophomena depressa, S. pecten, S. imbrex, S. funiculata, S. euglypha, and *S. antiquata;*
Leptæna transversalis;
Obolus transversus; Orthis elegantula, O. biforata;
Atrypa reticularis, A. marginalis;
Spirifer elevatus, S. plicatellus;
Athyris tumida;
Rhynchonella nucula, R. deflexa, R. Grayii;
Pterinea (?) *planulata;*
Euomphalus discors, E. funatus;
Orthoceras annulatum.

With a few corals, such as—

Heliolites interstinctus;
Thecia Swindernana;
Favosites alveolaris (or *F. Gothlandica*);
Halysites catenularius—the chain coral;
Cyathophyllum truncatum, C. angustum;
Omphyma turbinatum (the largest of the Silurian cup corals);
Aulopora serpens, which is now found to be the creeping base of a *Syringopora* or tube-coral.

* See Magazine of Nat. History, vol. 2, p. 41, figs. 8, 9, 10, 1829.

It will be seen that this is a Wenlock Limestone list, and there are, indeed, few localities where the Woolhope band possesses any great distinctive character to separate it from the Wenlock. At Presteign, Radnorshire, it has, perhaps, the most peculiar facies. (See "Siluria," 2nd ed., p. 118.)

3. A few localities in the WENLOCK SHALE, such as the "Five Lanes" near Walsall, and the Bell in the same neighbourhood, are full of the characteristic fossils; a few are not known in the beds below. There are the ordinary brachiopod shells above mentioned, with *Strophomena imbrex* of Davidson, and *Obolus transversus;* the last is most abundant. This curious shell occurs also in the May Hill sandstone (but not of this district). *Pentamerus galeatus* and *Athyris tumida*, two or three species of *Pterinea*, especially the *Pt.* (?) *planulata*, which grows to a large size, *Cardiola striata*, a Lower Ludlow shell, *Acroculia Haliotis*, *Bellerophon*, *Phragmoceras pyriforme*, and a smooth *Orthoceras*, *Encrinurus punctatus*, and *Phacops caudatus*, are the common trilobites. *Ptychophyllum patellatum* and *Heliolites inordinatus* are conspicuous corals in the shale.

4. The WENLOCK LIMESTONE (divided into two bands by a thick layer of shale, as above described) contains all the fossils above noted, with the addition of a host of others. Indeed, the quarries of Dudley are the most famous in the world for Upper Silurian organisms. Shells, corals, encrinites of very numerous genera and species, and trilobites, are all in a state of perfection such as no other locality in Britain exhibits. The well known collections of Messrs. Gray and Fletcher at Dudley, and the cabinets of nearly every public museum in Britain or elsewhere, are evidences of the great labour expended in collecting and developing these beautiful remains. A mere list of them would include nearly all the Upper Silurian forms in Britain. It will be necessary, therefore, to give only the more striking forms. The asterisks denote the comparative abundance of the species.

Among the trilobites the following are conspicuous:—

Calymene Blumenbachii *****, the Dudley trilobite or Dudley locust, an universal Silurian fossil.

Homalonotus delphinocephalus, a fine species, more common in the Woolhope limestone.

Lichas Anglicus ****, and *L. Barrandii*, with three other species.

Acidaspis Brightii ***, *A. quinquespinosa* ***, *A. crenata*, the large *A. Barrandii*, ***, &c.

Staurocephalus Murchisoni, found also in Lower Silurian rocks and in Bohemia.

Cheirurus bimucronatus *, and *Sphærexochus mirus* ** (this last ranges to America).

Encrinurus punctatus ******, and *E. variolaris* ******, the strawberry-headed trilobites of Dudley, among the commonest of all the Dudley species.

Phacops Downingiæ ****, *P. Stokesii*, and *P. caudatus* **, all of them very common species.

Proetus latifrons, M'Coy, with another species, and the beautiful little *Cyphaspis megalops* ****, in which last, as well as in several other species above mentioned, the Dudley specimens show more or less clearly both sexes—the males narrower and with longer spines than the females.

Then of other classes, the *Annelida* for instance, we have *Cornulites serpularius* and *Tentaculites ornatus* in myriads. Dudley is especially rich in corals and *Crinoidea*. Of the last, multitudinous species are in

the hands of Messrs. Fletcher and Gray, and are yet unpublished. The *Cystideæ* belong to another order of Echinoderms, and of these there are no less than ten species of the genera *Apiocystites*, *Echino-encrinites*, *Ischadites* (a doubtful Cystidean), *Prunocystites*, and *Pseudocrinites;* all which are described by Prof. Forbes in the Memoirs of the Geological Survey.* Of true Crinoids we have no less than 23 forms already catalogued, but double that number are yet undescribed. Among the more conspicuous are the *Crotalocrinus rugosus*, a crinoid with net-like arms and a singular tuberculate stem, covered at its lower part with root-like processes.

Cyathocrinus, four species.

Dimerocrinus decadactylus and *D. icosidactylus*. The names imply the difference of character in the arms.

Of the genus *Eucalyptocrinus*, with its massive stomachal plates, two species occur at Dudley, *E. decorus* and *E. polydactylus*, and one at Walsall, *E. granulatus*. *Platycrinus? retiarus* is not rare.

Cheirocrinus serialis is a remarkable pendulous form. *Marsupiocrinus cœlatus*, two species of *Pisocrinus* (a minute fossil), *Taxocrinus tuberculatus*, and *Icthyocrinus pyriformis*, with *Glyptocrinus expansus*, are quite common fossils; and the long necklace-like stems of *Periechocrinus moniliformis* occur on almost every slab of Dudley limestone.

The corals are still more numerous, and though there is no evidence that the Dudley limestone possessed the character of a coral reef, yet the floor of the sea must have been nearly covered with them. They are chiefly solitary forms, however, never exceeding a foot or two in diameter, and even this is rare. The more massive compound ones are *Acervularia ananas*, *Arachnophyllum typus*, *Cyathophyllum truncatum*, *Favosites alveolaris*, and *F. Gothlandica;* the chain coral, and *Heliolites interstinctus;* occasionally one or other of the five species of *Syringopora*. *Sarcinula organum*, Linn., is more commonly Lower Silurian. Of the large cup corals, *Cystiphyllum Siluriense* and *C. cylindricum*, *Cyathophyllum angustum*, *Ptychophyllum patellatum*, and *Zaphrentis lata*, are conspicuous, with *Omphyma turbinatum*, the largest and commonest of all. Three species of *Palæocyclus*, a little mushroom coral, are beautiful forms. The smaller *Millepores* and branched corals are the most numerous. *Alveolites Labechei*, *A. repens* and *A. seriatoporoides*, *Chætetes Fletcheri*, *Cœnites intertextus*, *C. juniperinus*, and *C. labrosus* are minute-celled species. *Favosites cristata* has larger tubes. Two or three species of *Heliolites*, such as *H. Grayi*, *H. petalliformis*, and *H. tubulatus*, *Labechia conferta*, *Thecia Swindernana*. The last four species are everywhere found in Wenlock limestone.

There are a good many minute coral-like forms now more correctly referred to the *Bryozoa*, some of which are encrusting and parasitic (*Diastopora* and *Discopora*), others have free cup-like or net-like fronds, *Fenestella*, *Polypora*, *Glauconome*. Some are foliaceous, like the *Eschara* of our coasts; *Ptilodictya lanceolata* and *P. scalpellum* represent these, and are very common species.

Many of the *brachiopod* shells have been quoted above from the lower limestone band. To these the following must be added, and the more abundant ones are indicated by asterisks:—

	D. Dudley;	W. Walsall.
Orthis Bouchardi -	-	- W.**
O. Lewisii -	- D. -	- W.
*O. hybrida***** -	- D. -	- W.*****

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	D. Dudley;	W. Walsall.
O. biloba ****	D. -	W. *****, very large.
O. rustica **	D. -	W. *****
O. var. *rigida* **	D.	
O. calligramma, var. *Davidsoni*	D. -	W.
var. *Walsalliensis*	-	W.
Strophomena filosa	D.	
S. antiquata, large (*S. scabrosa*, Davidson)	D. ****, these are but one species.	
Spirifer sulcatus	D. ****, a minute species.	
Sp. plicatellus	D. *******	
Sp. var. *interlineatus*	D. **	
Sp. var. *globosus*	D. ****	
Sp. trapezoidalis	D. ****	W.
Sp. crispus	D. ****	W. ***
Pentamerus galeatus	D. ****	
Rhynchonella Stricklandi	D. ******	
Rh. deflexa		W. *****
Rh. didyma		W. *
Rh. Wilsoni	D., several varieties.	
Rh. borealis	D. ****	
Rh. Lewisii	D. ****	
Retzia cuneata	D. ****	
R. Salteri	D. ****	
R.? Capewellii	D. **	W.
Discina rugata	D.	
D. Forbesii	D. *	
Crania (a radiated species)	D.	

There are but few lamelli-branchiate shells; *Orthonota cingulata*, however, is not uncommon, and

Pterinea retroflexa **	D.	
P. Danbyi, or allied species	D.	
Avicula mira, Barrande	D. ***	W. ***
Mytilus mytilimeris	D. *****	W. *****
Ctenodonta Anglica	D.	

are a few of the more ordinary forms.

Of *Pteropods* and ordinary spiral shells, *Conularia Sowerbyi* is abundant enough, and of several varieties, and probably there is another species.

Murchisonia Lloydii, *M. undata*, *M. balteata*, *M. articulata*, and at least seven other species, chiefly from the limestone.

Euomphalus alatus, *E. funatus*, *E. sculptus*, *E. discors*, *E. rugosus*, *E. carinatus*, and two or three undescribed ones.

Cyclonema carinata, and *E. corallii*; *Turbo cirrhosus?*; *Macrocheilus*; *Natica*; *Acroculia prototypa*, and *A. Haliotis*, with many species as yet unnoticed of all these genera.

Lastly, there are several *Cephalopodous* shells, though most of these are among the rarer forms.

Orthoceras annulatum and its variety, *O. fimbriatum*, is most common.

Phragmoceras pyriforme occurs at Dudley, *Lituites cornu-arietis*, and *L. tortuosus* are only occasionally met with.

There are several rarer fossils, which we can scarcely do more than notice here; among others, two species of *Chiton*; an *Ischadites*,

distinct from *I. Kœnigii*; *Pleurorhynchus æquicostatus*; new species of *Bellerophon*; *Pleurotomaria*; *Chemnitzia*; *Cyclonema*; and other spiral shells. We may hope to have several of the new species published under the auspices of the Palæontographical Society.

The limestone was evidently a deep-water formation, and very tranquilly deposited.

5. Lower Ludlow.

Of the next succeeding or Lower Ludlow formation no list has been yet published. From the neighbourhood of Parkes Hall a good many species have occurred to the persevering search of Mr. John Gray. The following are a few of these. Bivalves seem to have been the most abundant, such as—

Orthonota semisulcata, *O. impressa*, *O. rigida*, *O. amygdalina*; *Pterinea lineatula*, *P. Sowerbyi*; *Avicula ampliata* and *A. mira*; *Mytilus mytilimeris*; *Goniophora cymbæformis*; *Schizodus*; *Cardiola striata*; and many others.

Several of the *Brachiopods* which occur in the limestone are also found in the shale, and need not be repeated here.

The *Lingula Lewisii* and *Discina rugata*, *D. striata*, and a new species, are frequent. *Strophomena euglypha*, *S. depressa*, &c. *Orthis* is rare. *Spirifer interlineatus*, *Pentamerus galeatus* and *P. linguifer*, *Althyris tumida*, and *Rhynchonella Wilsoni*, are some of them.

Spiral shells are numerous, though not of many species.

Pleurotomaria undata, and a new discoid species; *Murchisonia Lloydii*; *Euomphalus alatus*; *Conularia*; *Cyrtolites*, large and fine specimens; *Bellerophon dilatatus*, *B. trilobatus*, of very large size, and at least two other species; of *Cephalopods*, *Orthoceras angulatum*, *O. bilineatum*, *O. annulatum*, *O. perelegans*, *Phragmoceras compressum*; the large *Lituites giganteus*, and the small and rarer species, *L. articulatus*, all occur in these prolific shales.

Encrinites and corals are but scarce; and of *Bryozoa* only *Ptilodictya lanceolata* has yet been found; *Trachyderma squamosa*, an annelide common in the Lower Ludlow rocks of other localities, is found also here. There are six or seven species of trilobites, the *Calymene* and *Encrinurus variolaris* being the chief. *Phacops caudatus* is not uncommon; and the valves of a large *Ceratiocaris* are in Mr. John Gray's collection.

6. Aymestry Limestone (Sedgley, &c.)

But few fossils have been collected from this band, which nevertheless has an historical interest in connexion with the Silurian System. The limestone of Sedgley was clearly distinguished from the underlying Wenlock bands by the late Rev. T. T. Lewis, who correctly compared it with his native Aymestry rocks. The *Pentamerus Knightii* is found in it abundantly, but it is worth notice that this most characteristic shell occurs (though rarely) in the Wenlock of this very locality, and also of Presteign. It is also found in the Lower Ludlow rocks of several districts. Its true place is, however, clearly in the Aymestry limestone. At Sedgley, at the Beacon Hill, and at the Park School, some of the other Aymestry fossils have been found, viz., *Phacops caudatus*, the common *Atrypa reticularis*, *Spirifer plicatellus*, variety *interlineatus*, and *Rhynchonella Stricklandi*, together with *Strophomena depressa*, a *Turbo*, and a cup coral. There must be many more if the rock were carefully searched.

From the Upper Ludlow rocks, if they exist above these, no organic remains have yet been collected.

The chief peculiarity in the Silurian strata in this district is the separation of the Wenlock limestone into two bands. The same fossils occur in both bands and in the intermediate thick band of shale.

The list above given is the first corrected catalogue, I believe, yet published of the rich fauna of the Dudley limestone. It might be greatly extended.

J. W. S.

CHAPTER VIII.

DESCRIPTION OF THE ROCKS—*continued.*

Igneous Rocks.

THERE are two varieties of igneous rock in the district; namely, Basalt and Greenstone, and another apparent variety, differing greatly from both in mere external characters. All three, however, are different parts of the same great mass of molten matter, their variety depending probably more on the conditions under which they have been placed than on any difference in the origin or mineral constitution of the rocks themselves.

The "Rowley rag" is a Basalt, a hard, heavy, black, close-grained rock, weathering brown outside, having a tendency to form spheroids that envelope with several concentric coats a solid ball in the middle, and consequently often assuming a columnar structure, which in some instances becomes nearly as regular as that of the Giant's Causeway. This is the stone of the Rowley Hills, Barrow Hill at Pensnett, Pouk Hill at Bentley, and other spots.

Of this rock an analysis has lately been made by Mr. Henry of London, for Mr. S. H. Blackwell, of Dudley, who has kindly placed it at my disposal.

Composition of Rowley Rag (specific gravity 2·907).

Silica	49·860
Alumina	12·750
Lime	8·710
Magnesia	4·395
Protox. iron	11·380
Perox. iron, with manganese	3·360
Soda	5·250
Potash	0·570
Titanic acid	1·330
Phosphoric acid	0·580
Water	2·560
	100·745

Burrowing in the Coal-measures, and here and there coming out to the present surface, is another igneous rock called "green rock" by the colliers. This is generally, if not always, the true "Greenstone" of mineralogists, composed of orthoclase and hornblende,*

* On the authority of Sir H. De la Beche.

sometimes fine-grained or compact, sometimes largely crystalline. It contains sometimes fibrous radiated masses and plates of some zeolitic minerals.

From this Greenstone proceed dykes and veins of "White rock" trap, which at first sight might be mistaken for a compact sandstone, but when closely examined bears a greater resemblance to a partly decomposed, white, compact, and somewhat earthy felstone. In some places little shining facets of feldspar may be detected in it. The colliers all unite in stating that this "white rock" proceeds from the "green rock," and though I have never myself seen the junction of the two rocks, I have no doubt of the fact. That the "white rock" is an igneous rock, as well as the "green rock," is proved by its cutting through the coal and other beds in the same way that the green rock does, and by its producing the same amount of alteration in them.

A specimen of this trap was analysed by Mr. Henry, which gave the following results:—

Silica	38·830
Alumina	13·250
Lime	3·925
Magnesia	4·180
Soda	0·971
Potash	0·422
Protox. iron	13·830
Perox. iron	4·335
Carbonic acid	9·320
Water	11·010
	100·073

This composition shows us at once that the rock cannot belong to the siliceous class of the Felstones or Trachytes, but is one of those basic compounds to which the Greenstones, Diorites, and Dolerites belong. Moreover, the presence of so large a per-centage of carbonic acid and water shows that the rock has now a different composition from that which it possessed before the period of injection, when it was in a molten condition. It is, in fact, an altered rock, altered by having had so much carbon, oxygen, and hydrogen added to it as to give it a per-centage of 20·330 of carbonic acid and water. If we deduct those materials from Mr. Henry's analysis, and reduce the remainder to per-centages, we get—

Silica		48·8
Alumina	16·7	22·1
Peroxide of iron	5·4	
Lime	4·8	29·0
Magnesia	5·2	
Soda	1·2	
Potash	0·5	
Protox. iron	17·3	
		99·9

A composition quite sufficiently near to that of a basic kind of greenstone or basalt for us to look upon it as one.*

I shall not venture to intrude into the province of the chemist so far as to speculate on the way in which these additions were given to the rock, except by observing that the rock penetrates coal, and that the three ingredients acquired, namely, carbon, hydrogen and oxygen, are the essential constituents of coal.† Neither will I attempt to decide whether the infusion of these materials into the mass of the rock took place immediately on its injection into the coal, and while it was cooling and consolidating, or whether it was the result of the slow and gradual process of purely aqueous infiltration during long subsequent periods.

Basalt.

Rowley Hills.—Of the basaltic rocks, the largest exhibition is that on the summit of the Rowley Hills. A capping of columnar basalt here rests upon the Coal-measures, over an irregular space two miles long by more than a mile in width at one part. This capping seems to be of irregular thickness, as it is largely quarried at some places on the side of the hills at least 100 feet below their summits; while on the line of the new Netherton tunnel of the Old Birmingham Canal no basalt was met with in any of the shafts, not even in the highest, which is very little below the crest of the ridge.

These shafts, however, seem to have passed through some pale green rock, slightly schistose and ashy-looking, with a crystal of feldspar here and there in it. There are also to be seen occasionally, on the slope of the hill just below the basalt, some considerable beds of trappean breccia, or brecciated ash, containing

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* M. Durocher, in his Essay on Comparative Petrology, gives the following as the mean composition of Basalt and Diorite, of which latter term we may consider Greenstone as the English synonym :—

	Diorite.	Basalt.
Silica, with trace of Titanic Acid	53·2	48·0
Alumina	16·0	13·8
Potash	1·3	1·5
Soda	2·2	3·0
Lime	6·3	10·2
Magnesia	6·0	6·5
Oxides of Iron and Manganese	14·0	13·8
Loss by ignition	1·0	3·2
	100·0	100·0

(Essay on Comparative Petrology by M. J. Durocher, translated from the Annales des Mines, vol. xi., 1857, by Rev. S. Haughton. Dublin, M'Glashan and Gill.)

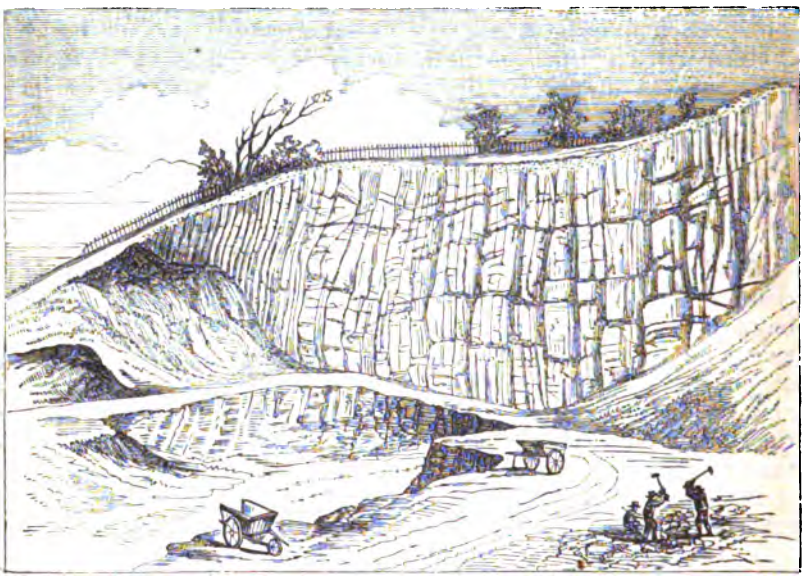
† According to Bischof, bituminous coal may be taken as essentially composed of—

Carbon	82·1
Hydrogen	5·5
Oxygen and Nitrogen	12·4
	100·0

independent of a variable admixture of earthy matter forming the ash.

rounded and angular fragments of igneous rock lying in a brown, rather ferruginous paste, that looks like the *débris* of a basaltic rock.

Fig. 12.



Coxe's Rough, Basalt Quarry.

If these beds be connected with the basalt, which seems almost certain, it shows that the basalt was an *eruptive** rock, poured out at the surface in the form of a *sheet of lava*, whether subaqueous or subaerial, immediately after the formation of the part of the Coal-measures which lie below it. These trappean breccias or conglomerates belong to and pass into the Coal-measures, and therefore the basalt of the Rowley Hills also belongs to and forms part and parcel of the Coal-measure series. That it was formed during the Coal-measure period seems also to be probable, from the fact that it has been subsequently affected by all the dislocations and other accidents that have happened to the Coal-measures.

The Netherton tunnel has lately been driven right through the base of the ridge between Oakham and Farnley Hill, running from Tividale to near the Gads Green reservoir. Eight or nine shafts were sunk from the surface along the line of this tunnel down to its level, which is that of the canal at Tividale, or 484 feet above the sea. Neither in the tunnel nor in any of the shafts

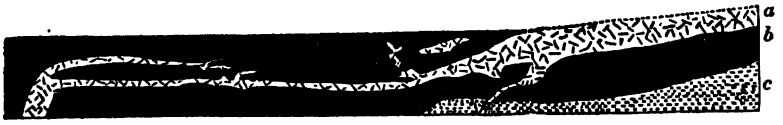
* This term of "eruptive" is sometimes applied to granitic rocks, which, however intrusive they may have been, clearly cannot have been *eruptive*, that is, can never have burst out to the surface. I would, therefore, by an eruptive rock mean only such a rock as could have been ejected out of the earth and poured over its surface, whether that surface was there covered by air or by water.

was any solid basalt met with, though one or two strings or tortuous veins of trap seem to have been cut through in the tunnel.*

The mass of the rock passed through both in the tunnel and the shaft consisted of a reddish and greenish coloured clay or shale and sandstone, sometimes the argillaceous, sometimes the arenaceous character predominating. The sandstones often contained pebbles, and thus passed into conglomerates. It was only in the upper shafts, those numbered 5, 6, and 7, that the green ashy rock mentioned above seemed to have been got, so far as I was able to judge from an examination of the spoil banks.

The Thick coal has been worked round three sides of these hills, and it appears generally to dip under and pass beneath the basalt. On the north side only, however, has it been followed under the basalt, and that for but a very slight distance; and in every instance in which this has been attempted the coal has been found to be "blacked" and to be fractured, and frequently to pass into "rock and rig." A coal is said in this district to be "blacked" when, by its near proximity to an igneous rock, it has become so altered as to lose all its brightness, and nearly, if not quite, all its inflammability. It is not exactly coke, but is dull and earthy, and on exposure to the atmosphere is very friable. It frequently in this state contains small nodular concretions of iron pyrites. I have never had the opportunity of examining a pit where the coal was thus affected, except Mr. Percy's pit, now belonging to Dr. Percy, at the Grace Mary colliery, a little east of Rye Cross Farm. Here, at a depth of about 200 yards, they came into blackened coal, penetrated by long dykes of white rock trap, and more or less intermingled and mixed up with white sandstone. This white sandstone was full of little patches and shreds of coal, and the coal was frequently entangled in the sandstone, and the two mixed up together in a very singular way. This kind of sandstone is that called by the colliers "rock and rig" In one of the gate-roads of this colliery the white trap ascending from the floor, or descending from the roof, cut both into the coal and the sandstone, in the manner shown in Fig. 13.

Fig. 13.



Scale, 20 feet to 1 inch.

a The white-rock trap.
b The coal.
c White sandstone (rock and rig).

This was drawn to scale with a measuring tape, and is a sufficiently accurate representation of the facts. A little north-west of this part of the mine a fault was met with, beyond

* Mr. Walker, jun., who superintended the works of this tunnel, was good enough to let me see a large section constructed from the workings, from which the above statements were taken.

which the Thick coal was found uninjured either by trap or by "rock and rig."

On a subsequent visit to these pits in 1858, I examined, with Mr. Cooksey, some gate-roads that had been driven in a southerly direction, or towards the part of the ground which is capped by basalt. The sandstone called "rock and rig" came in in larger quantity in that direction, as before described, p. 50, and the veins of white rock trap became very numerous. In one of the gate-roads a horizontal vein of trap, about a foot, or a foot and a half, in thickness, ran horizontally and regularly in the middle of the coal for 40 or 50 yards, looking precisely like a deposited bed, but then suddenly cut up across two or three beds of coal, sent off a number of irregular strings and bosses into the coal, and then shot off again horizontally near the roof for some distance, see Fig. 14. The mass of this coal was a perfectly clean, bright coal, with brilliant surfaces on the face and joints. For a distance of 6 inches to 12 inches, however, from the trap the coal was "blacked," that is to say, it was dull and friable, with an earthy look, having neither the dice-like division into lumps, nor the brilliant shining surfaces which the rest of the coal had.

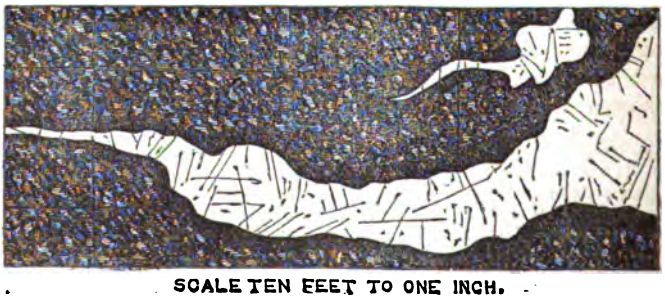
Fig. 14 will give the representation of these facts from a sketch made on the spot with as much care as I could draw it, the white part representing the trap, the black border round it the altered coal, and the mottled part the coal retaining its brilliancy.

Fig. 14.

SCALE FIVE FEET TO ONE INCH.

Fig. 15 is taken from another sketch made on the same occasion, showing the termination of a considerable mass of this trap, and a little isolated boss of it in the coal.

Fig. 15.



SCALE TEN FEET TO ONE INCH.

All parts of these galleries, indeed, were riddled as it were with these trap veins running here and there in the coal, and also in the sandstone, altering the coal to a greater or less extent according to the bulk of the trap, but producing very little apparent alteration in the sandstone.

The men in this colliery call this white rock the "door-case rock," because in one of the gate-roads formerly driven in the part of the coal which is generally devoid of trap, an upright vein of it crossed the gate-road like a wall, and appeared when cut through like a white door-case in the black coal.

From the fine tortuous and branching veins which this rock forms, it seems hardly possible to suppose that at the time of its injection it was not in a fluid state, and almost perfectly liquid. The distances to which these narrow veins run seem also to make it necessary to suppose that at the time of injection it had a temperature not merely just sufficient to melt it, but a much higher one, sufficiently high to allow of the loss of a considerable quantity of heat, and yet for the matter to remain still molten in its passage to very considerable distances from the volcanic focus. Doubtless the injection was a rapid one, but still some heat must be lost in the passage of these comparatively thin sheets of molten matter over such very considerable areas.*

Now, if masses, however comparatively small, having such an intense heat as above supposed, come in contact with a substance so easily affected as coal, we should at first expect it to be almost entirely consumed, or at all events altered to a much greater extent than it appears to have been. Our ideas, however, are derived from witnessing the effects of heat at the surface, and in contact with the atmosphere. Might not these ideas lead us astray, if we reasoned from them as to what would take place at some depth in the earth, unless we made allowance for the total or nearly total absence of air, and the effect of the covering of rock, which would greatly obstruct the dissipation of the constituent gases of the substance acted on, rendering that dissipation very difficult and therefore very small?

Is it altogether impossible that the nature of the alteration was rather the extraction of a certain portion of the hydrogen and oxygen of the coal, together with some of its carbon, and the combination of those substances with the oxides previously existing in the igneous matter, rather than the expulsion of those gases into the rocks above or below the coal? In this way the greatest amount of metamorphosis would be produced in the substance of the igneous rock, some part of the matter of the coal being actually absorbed into it and used up by it, and its constituents combined with its own as it passed along. The blackened margin of the coal

* M. Delesse, in his "Etudes de Metamorphism," supposes in these cases that the intrusive rock had not such an intense temperature, but that it was mixed with water into a state resembling mortar. It does not appear to me, however, possible for a mere paste to be injected into fine crevices to such great distances as we find in the above and other cases.

about the igneous rock would then represent that small part of the coal that was altered by having some of its gaseous constituents sucked out of it, as it were, leaving a coating of nearly pure carbon as a non-conductor to protect the remainder of the coal.

The only explanation of the occurrence of the sandstone called "rock and rig" I can offer is, that it is part of a "rock fault," a mass of sandstone contemporaneous with the coal, as described before, p. 48. Whether its connexion with the trap be accidental or otherwise it is difficult to determine. I am inclined to think, from the frequency of the occurrence of these "rock faults" in the coal in the neighbourhood of the Rowley Hills, and their absence, so far as I know, at any great distance from them, and from "rock and rig" being found around Barrow Hill, that their connexion with the trap is not accidental. It seems possible that the volcanic focus from which was subsequently protruded the molten basalt, gave some indication of its existence, even at an early period in the formation of the Coal-measures; and that from some troubled action fracturing the rocks, and either generating springs that brought up sand from below, or causing currents, perhaps of considerable local intensity, in the water above and around, which might sweep in sand from a distance, sandy beds might be deposited that locally interfered with the production of the Thick coal.

We have as yet no means of ascertaining the focus or centre of eruption from which the basalt of the Rowley Hills was poured out, and from which the sheets and veins of greenstone and "white rock" trap proceeded. No central pipe or funnel has yet been met with, but, except in the Netherton tunnel, no large exploration has yet been continued beneath the basalt.

The deterioration of the Thick coal by the quantity of sandstone that seems to come into it as the hills are approached is one reason for its not having been followed as yet beneath them. The fear that the coal which may exist is partly destroyed by trap rock is probably another reason.

It may still happen that at some point round the Rowley Hills *good unaltered* coal may be found for some distance beneath the basalt, but at present all the known evidence is the other way.

Barrow Hill.—Barrow Hill, two miles west of Dudley, is another mass of basalt in every respect similar to that of Rowley, except in extent and in its position with respect to the Thick coal. The Rowley columnar basalt seems to lie at a height of about 600 feet above the Thick coal, that of Barrow Hill is apparently at a much less height. If they are each contemporaneous with the beds in which they lie, it follows that the Barrow Hill trap is older than that of the Rowley Hills. Immediately east of the hill, it appears, from the marks of old workings, that a piece of Thick coal cropped to the surface, and was worked in open work along it. This piece lay in an angle between the Corbyn's Hall fault and another, which is supposed to run south of Barrow Hill. In the workings to the west of Barrow Hill the coals are found to be "blacked" as they approach it, and beds of "green rock" (horizontal dykes) are

found between the measures to the east for a distance of about two miles.

Pouk Hill.—Pouk Hill, near Walsall, is another mass of columnar basalt of less size than Barrow Hill, but equally, or still more, interesting.

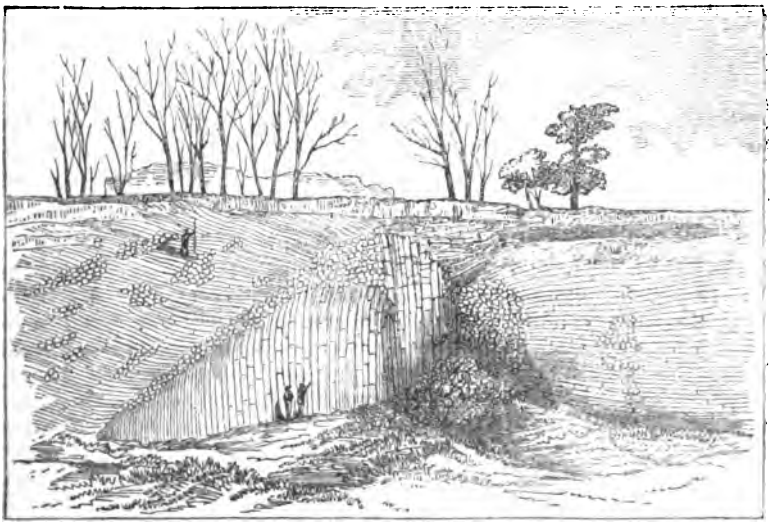
It lies altogether below the Thick coal and between the Fire-clay and the Bottom coal.

It formed a small slightly prominent mound of about 100 yards across, but this is now nearly all quarried away. The quarry, however, in 1858, exposed the structure of the rock in an admirable manner, and showed that structure to be very interesting and peculiar.

In the centre of the quarry the columns, which were often very regular, were vertical over a space of some 20 yards in diameter. In the middle part of this space the columns continued vertical till they reached the surface, but on the western side the tops of these vertical columns curved in for the space of a yard or so, and were at last quite sharply bent inwards so as to have the transverse section of the columns facing towards the centre of the quarry. The line along which this curvature took place sloped obliquely down from the top of the quarry to the floor at an angle of about 35°, and above that line all the columns lay in a position more nearly approaching the horizontal than the vertical. The ends of the columns slightly curved up along the line of junction so as to become nearly parallel to the bent tops of the vertical columns, and rose in the other direction into angle of about 20°, so as to suggest the idea of a radiation from this inclined line of junction.

Fig. 16.

Sketch of Pouk Hill Quarry as it was in October 1858.



On the eastern side of the quarry the columns likewise lay in slightly bent, but nearly horizontal lines, though here the change

from vertical to horizontal was in one part more abrupt and in another seemed to have been more irregular. The state of the working of the quarry, too, obscured the relation of the columns on that side. A number of uncompressed spheroids of basalt appeared in one part along the line of junction of the vertical and horizontal columns.

On the south-east side of the quarry the black shales of the Coal-measures might be seen reposing on the basalt, which just below them consisted chiefly of uncompressed balls of basalt, bedded in a mass of decomposed basalt or basaltic "wacké" or clay. A small cutting for a tramway led from the quarry south to the canal, and following down this the Coal-measure shales containing ironstone were seen lying nearly horizontal. At one part these shales were traversed by a small dyke of white rock trap cutting across them at an angle of about 60° with the horizon, and rather more than a foot in width. Farther down this cutting, in consequence of a slight rise in the measures, the basaltic clay earth containing balls of basalt again made its appearance for a few yards, and then finally sank out of sight towards the south.

The columns of Pouk Hill, doubtless, assumed the radiating form above described in obedience to the rule they are known generally to follow, that, namely, of always striking from the cooling surfaces of any mass towards the interior. Thus, in a horizontal sheet the columns are vertical, in a vertical dyke the columns are horizontal, and in a spheroidal mass the columns seem to radiate from the centre, or in other words strike from all sides towards it.

Netherton.—A mass of basaltic trap is very well seen in the canal cutting south of Netherton church, where it is exposed by the rise of the beds below the Thick coal, and is seen to send wedge-like masses into the Coal-measure sandstones.

Greenstone.

Sheet-like masses of "green rock" (the local name for the greenstone) seem to spread almost uninterruptedly in the lower Coal-measures from the base of the Rowley Hills and Barrow Hill, through the centre of the district up to Wolverhampton, Bilston, and Bentley.

At Barrow Hill Coppice pits 64 feet of "green rock" penetrated the Gubbin-stone measures just beneath the Thick-coal. At the Birds Leasowe colliery, near Tansey Green, the Thick-coal was found to be "mingled with rock and rig;" and, below the Gubbin measures, "green rock" was found, into which they sunk 38 feet. Between Tansey Green and Shut End furnace the "green rock" is only 36 feet thick, and comes in in the place of the Heathen coal, the Thick coal itself being blacked. To the east of Barrow Hill a sheet of "green rock," which at first is more than 60 feet thick, but afterwards thins to about 30 feet, stretches for at least two miles in one direction. Its usual place is between the Heathen coal and the Whitestone measures, but between Cooper's Bank and the Fiery Holes the "green rock" cuts down under the Whitestone measures. This "green rock" crops regularly out like

a bed on the rising ground west of Russell's Hall, and intrusive bosses of it rise to the surface at a spot on the western outskirts of the town of Dudley, at the Fiery Holes, at the east side of Cooper's Bank, and in the brook to the west of it.

At one of Lord Ward's pits at Tividale (about a quarter of a mile north by west of Coxes Rough) they found, at a depth of 500 feet, the following beds :—

	FT.
1. Coal mingled with rock, representing Thick coal -	24
2. White rock, *sandstone* - - - -	33
3. Strong rock - - - - - -	9
4. Binds - - - - - -	6
5. Gubbin measures - - - - -	2
6. Coal mingled with rock (represents Heathen coal) -	4
7. Green rock, sank into for - - - -	27

The usual distance between the Thick coal and the Heathen coal is only 12 or 14 feet, instead of 54, as here ; Nos. 2 and 3 being quite unusual measures.

At Dudley Port, in Mr. Bagnal's limestone pits, they passed through 15 feet of "green rock" in the lowest sandstone of the Coal-measures, just before entering the Silurian shale.

At Tipton Moat colliery and at Tipton there were 34 feet of "green rock" at a distance of 36 feet below the Bottom coal. At Deepfields they got 20 feet of "green rock" at a depth of 39 feet below the Bottom coal. At Highfields they found the "green rock" at a depth of 66 feet below the same coal, and sank into it for 15 feet only. At Bradley, in Mr. Addenhook's colliery, they found the "green rock" 55 ft. 6 in. thick at a depth below the Bottom coal of 24 ft. 6 in.

Near Bilston, in a pit in a field called Crabtree piece, Messrs. W. and J. W. Sparrow found 15 feet of "green rock" 22 feet below the Bottom coal ; and at the Wallbutts colliery the "green rock" was struck 27 feet below the Bottom coal, and sank into for 10 feet.

No "green rock" has been seen cropping to the surface on the rise of the lower measures on the north-east flank of the Dudley and Sedgley ridge ; nor, so far as I am aware, has any been met with east of Darlaston or Wednesbury, or about West Bromwich, either at the surface or under ground. A considerable boss of it is seen, however, in the canal bank between Moxley and the Broadwater furnaces, which must either belong to another mass or must cut up through the Thick coal and the beds above it to reach the surface. It may also have been met with in other situations in the workings of which the record is now lost.

In the district between Wolverhampton and Walsall "green rock" is frequently met with in sheets in the lower measures, varying in thickness from 15 feet to 80 and 90 feet. In the southern part of this tract it lies *below* the Bottom coal, but between Wolverhampton and Willenhall it cuts up through that coal) and to the north of that is always found *above* the Bottom coal, between it and the Fire-clay coal. A boss of it rises to the surface, cutting up through the New mine coal at the Heath colliery north-east of Wolverhampton, and a little north of that a large mass of it rises broadly out and forms the surface of the ground all around Wednesfield, as delineated in the map. In the Bentley district the basalt of Pouk Hill seams merely to be an irregular swelling of the bed of "green rock" that crops out a little further east along the bank of the canal. This bed is found in the underground workings for about half a mile to the westward of Pouk Hill,

and for the same distance to the northward, varying in thickness from 20 feet to 40 feet, lying always just above the Bottom coal, which is often greatly injured by it. It does not extend as far east as the Birch Hills,* nor far north towards Bloxwich, nor beyond Clark's-lane to the westward, neither was any found in Messrs. Bates's pits at the Trentham colliery between Mumber-lane and Wednesfield.

Near Wolverhampton none has been found in the Rough Hills, Cockshutts, or Parkfields collieries. At the Chillington colliery it is found, however, sometimes above, sometimes below the Bottom coal, and varying from 15 feet to 30 feet in thickness.

I was assured by Evan Lloyd, the ground-bailiff of the Chillington colliery, that there were two distinct beds of "green rock" there, as in the two following sections:—

Western part of the Chillington Colliery.

	FT.
1. Black and white ironstone	3
2. Bottom coal - -	12
3. Clunch - - -	24
4. Gubbin and balls ironstone	8
5. Slums - - -	3
6. Green rock, about -	35
7. Hard rock - -	12

Eastern part of the Chillington Colliery.

	FT.
1. Black and white ironstone	3
2. Green rock, about -	15
3. Bottom coal - -	12
4. Clunch - - -	24
5. Gubbin and balls ironstone	8
6. Slums - - -	3
7. Hard rock - -	12

Notwithstanding these facts the Gubbin and balls ironstone was worked continuously over the whole colliery without meeting any green rock. In this locality, therefore, there could have been no cutting up of the green rock through the measures, though it is by no means sure that these two sheets may not have a connexion elsewhere.

I was assured also by almost every one engaged in the works of this neighbourhood that, notwithstanding the variations in thickness of the "green rock," there was no change in the total thickness of the measures; that, for instance, the thickness between the New mine coal and the Blue flats ironstone remained the same, whatever might be the variation in the thickness of the "green rock." In other words, it was affirmed almost universally that the "green rock" not only intruded between the measures, but *obliterated* a mass of beds equal to its own thickness. This assertion was so confidently made by almost every *practical man* in the neighbourhood, that, however incomprehensible, I should have received it as true, had not an analysis of the materials received from them enabled me to disprove it. It is no doubt founded in fact; the greater the thickness of the intruded trap rock, the more intense, probably, would be the squeeze, and the consequent contraction suffered by the adjacent beds. Beds of coal, too, might certainly be nearly or altogether annihilated by the intrusion of molten rock, but we cannot conceive sandstone or clunch being thus destroyed. The truth is, that the original thickness of the measures was itself very variable, and it probably happened that, in one or two of the places where the facts were first observed, a partial thickening or thinning of the trap rock compensated for the reverse in the original beds. It may also have happened that the very fact of there being a local thinning of some of the upper measures gave occasion for a corresponding thickening of the intruded trap rock. That, however, the assertion before

* Beyond the Birch Hills furnaces, however, near Birch Hills Hall, trap is again found in the Coal-measures, about or above the place of the Bottom coal.

mentioned is really not borne out by the facts as to all places, may be shown by the following deductions from the pit sections furnished me in the district.

In six shafts in the Stow Heath colliery, partly in the occupation of Messrs. Sparrow, partly of Messrs. Ward, we find the following values for the thickness of the "green rock," and for the thickness of the whole measures, including the "green rock," from the top of the New mine coal to the top of the Blue flats ironstone :—

Pit.	Green rock.	Total beds from New mine coal to Blue flats.
	FT.	FT.
1.	30	164
2.	33	157
3.	51	205
4.	55	177
5.	66	204
6.	66	214

which shows that the total thickness does increase with the increase of the thickness of "green rock," although not regularly or in strict proportion, owing to the original irregularity in the thickness of the other measures.

In three pits at the Portobello colliery, just where the "hole" of "Moseley Hole," is engraved in the map, all three pits being within a distance of 264 yards, we get the following thicknesses :—

Pit.	Green rock.	Total from New mine coal to Blue flats.
1.	59	168
2.	56	104
3.	84	190

In which we find the increase in the total thickness to be very nearly in direct proportion to that of the green rock.*

In an open work in the New mine coal, some years ago, on Wednesfield Heath, a dyke of the white feldspathic-looking trap was seen cutting up into the coal from below, and ending in some black shale. In some quarries north of Willenhall the same rock may still be seen in veins cutting through the Coal-measures.

In the northern portion of the coal-field, north of Wednesfield, and Walsall, no trap rock is known to show itself at the surface of the ground, with the exception of a little spot of hard dark hornblendic trap at the Essington wood brick-kiln, only to be seen in a small quarry partially concealed by underwood, and surrounded by the red clays of the upper Coal-measures.

Much "green rock" was found in some old sinkings between Pool Hayes and the New Invention, obliging the works to be abandoned. I was informed that in some sinkings made by Colonel Vernon two or three miles north of Bloxwich on Essington Wood, the measures were found to be disturbed and altered by "white rock trap," to such an extent as to oblige them to abandon the undertaking. Large intrusive

* I have insisted a little more strongly on this point than its real importance deserves, because it is a good illustration of the error into which purely practical men are so apt to fall, that, namely, of over-hasty generalisation from insufficient data. The charge of "theorising," as it is called, is so often brought as a criminal charge against scientific men, that it is but fair to show those instances in which theory necessarily leads to truth, and therefore to safety, in order to counterbalance those in which it may occasionally have led to danger or expense.

masses of this white trap also are found in the pits near Birch Hills Hall, north of Walsall. At Union colliery, north of that, the Bottom coal is cut entirely out by "green rock;" and at Goscott, still farther north, there are six yards of "green rock" resting directly on the Bottom coal. White rock trap just shows itself in the cutting of the Cannock railway south of the bridge in the lane leading from Landywood to the turnpike road. In the rest of the field I have found no trace of the rock having been met with, and it certainly has not been seen in any of the Brereton workings at its northern apex.

Time and Mode of Formation of the Trap Rocks.—There is nothing in the mineralogical constitution of these igneous rocks that will give us any assistance in determining the geological period during which they were formed. I am not aware that the basalts of the Rowley Hills differ in any essential particular from those of the county Antrim (the Giant's Causeway, &c.), from those poured forth by existing volcanoes, or from basalt of any other period. The greenstone does not appear to differ essentially from the rock so called, which was formed during any period, from the Lower Silurian down to the most recent.

There appears, however, to be this difference in the circumstances under which basalt and greenstone were at any time formed: that while basalt is found in the lower part of the lava streams of existing and extinct volcanoes, and is therefore capable of being produced by the cooling of a molten mass on the surface of the earth, greenstone is not known to have been ever found to be so circumstanced, but always in such situations as either prove it to be an intrusive and comparatively deep-seated, or, at all events, not a superficially formed rock, or at least render it probable or possible that it was so formed.

Whether the difference between basalt and greenstone can be accounted for solely by the difference of the circumstances under which they cooled and consolidated from a molten mass into a solid rock, is a question I do not pretend to decide. My own belief is, that those circumstances exercised a preponderating influence on the distinction between the two rocks, and this belief is supported rather than opposed by the facts to be observed in the South Staffordshire coal-field.

If the ashy-looking beds associated with the Rowley basalt be really of the nature of "ash" or "tuff,"* then it follows, as a consequence, that the Rowley basalt is part of an actual lava stream poured out at the surface, either into the air or into the water. The time of this ejection was apparently after the formation of 600 or 700 feet of Coal-measures over the Thick coal, probably after the deposition of the red coal-measure clays, and about the commencement of that of the Halesowen sandstone group.

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* By "ash" or "tuff" I would understand the débris of an igneous rock, either produced by the action of water at the time of its being poured out, or immediately after, or by the action of steam or other gases rushing from the volcanic focus and ejecting the débris into the water, or into the air so that it ultimately fell into the water.

The intrusive sheets, dykes, and veins of "green rock" and "white rock" trap which burrow in the lower measures about the Thick coal and beneath it on the northern side of the Rowley Hills, and seem to spread through the centre of the district as far north as Wednesfield and Bentley, and thereabouts, may have commenced their intrusions some time before the outpouring of the Rowley basalt, which, giving a sensible and large relief to the struggles of the volcanic matter below, may have terminated the igneous action.

There may also be seen, in the neighbourhood of Barrow Hill, rocks having the character of ash or trappean débris, and it may be that that outburst of basalt likewise reached the surface, though from its position above the Thick coal it would appear in that case to have taken place at a rather earlier period than that of Rowley.

About Pouk Hill, there is no appearance of ash, and it seems to be so intimately associated with the horizontal sheet of greenstone, a short distance below, that I am more inclined to look upon that as a boss proceeding from it, not to the surface, but only *towards* the surface, and consolidating in an isolated mass at no great distance perhaps, below the surface of the rocks that existed at the period of its formation.

In all cases the isolated masses that are found in the higher parts of the Coal-measures are, I believe, basalt, while the wide spread horizontal sheets of igneous rock that spread over such large areas below, and occasionally make their appearance at the surface where the lower measures crop out, as about Wednesfield and to the east of Pouk Hill, are greenstone.

It is not by any means intended to insist too strongly on the superficial formation of the Rowley or Barrow Hill basalt, since except the occurrence of the ashy-looking beds, and the basalt being always above the greenstone, there is no conclusive evidence to show that these basaltic masses were not also intrusive sheets of igneous matter injected in between the beds of the Coal-measures.

If the basalts were outpoured lava streams, it of course follows that all the igneous rocks, taken as a whole, were contemporaneous with the Coal-measures, taken as a whole.

Even on the supposition of the igneous rocks being all intrusive, and therefore formed subsequently to the formation of the beds between which they now lie, I still think that we cannot assign a much later age to them, and that we shall be compelled to consider them as older than the Permian rocks.

The first argument in favour of this conclusion is a negative one, namely, that in this district no igneous rocks of any kind are found in any formation newer than the Coal-measures.

So long as the red clays of Essington Wood were considered to be of Permian age, this argument failed us as regards that formation, since there is a little boss of a peculiar kind of greenstone to be seen in a small quarry just west of the brickpits of that place. Now that these red clays are proved to be Coal-

measures, however, this occurrence of igneous rock in them becomes no exception to the general statement given above.

The second argument is of a more positive character, and is this, that *at whatever period these igneous rocks were produced, they were all existent before the production of the faults and dislocations that have traversed the Coal-measures, and before any great denudation had been effected on the country.*

The northern end of the Rowley Hill basalt is distinctly cut off by the extension of the northern of the pair of Dudley Port Trough faults and the southern of those faults seem also to have affected it.

The sheets of greenstone that spread from below the Rowley Hills, through the centre of the district, up to Wednesfield and Bentley, always run pretty nearly in the same beds, at whatever depth those beds may be found, and however they may be broken by faults. This shows that the "green rock" is itself cut through by the faults and thrown up or down by them, as the case may be, exactly as the Coal-measures are affected by them.

The same may be said in general of the sheets of "green rock" proceeding at a higher level from Barrow Hill. In each case the "green rock" crops out to the surface, along with the beds in which it lies; although as its thickness is very irregular, and as it shifts its place now and then in the beds, cutting up or down within certain narrow limits, above or below a particular set of beds, that outcrop has a corresponding irregularity and want of continuity.

This proves the igneous rocks to have been equally and similarly affected with the Coal-measures by the two great actions of "dislocation" and "denudation."

It seems quite impossible to suppose that if the faults existed before the "green rock" was injected into the measures, that it would not have taken advantage of those fissures to have made its way to the surface along them, rather than have forced itself in among and lifted up and floated a thickness of several hundred feet of beds over an area of several square miles. But since it is known for a fact that it is itself dislocated by these faults, as shown in the Horizontal (Longitudinal) Sections (Sheets 23, 24, and 25), that fact is conclusive in favour of the rock having been cooled and consolidated before those faults were formed.

My friend, Mr. S. H. Blackwell, indeed, informs me, that in the district west of Russell's Hall, south of Lower Gornal, where there are a number of step faults close together, the green rock there was found to go up into those faults. It certainly did not go up very far along them, since I believe it did not injure or intrude into the Thick coal, which there lies at no great distance above the "green rock." It may have sent veins up into the superincumbent measures along certain lines of slight resistance, which afterwards were converted into faults; or it is possible perhaps, that small dislocations were then caused before the time when the larger and more general dislocation of the coal-field was

produced. Or, lastly, with all respect to my friend Mr. Blackwell's acuteness of observation, (which no one will be more ready to acknowledge than I, who have so often profited by it,) he may have been led away by appearances which in the imperfect light of underground workings might have deceived any one. It seems to me quite possible that portions of the consolidated basalt may have been squeezed for some distance up into the fissures, and still more likely that some of the more decomposed parts (the clay or wacke, which often forms the covering of the hard rock) may have been so squeezed, at least as far as it was possible to follow it in underground explorations.

Whatever may be the exact state of the case with regard to this particular instance, the larger and more general fact remains undoubted, that there is no relation whatever either of cause or effect between the igneous rocks of the coal-field and the principal dislocations that have affected it; and that the igneous rocks all existed in and among the Coal-measures very much in their present condition before any of the great dislocations were commenced.

CHAPTER IX.

Original Relation of the Formations to each other as regards their Conformability or Unconformability.

I shall assume the conformability among themselves of the several members of the Silurian formation in South Staffordshire. This is rendered probable by their conformability in the neighbouring district of Shropshire, and there is no evidence against it in Staffordshire. Starting with that assumption, we must necessarily conclude that before the Coal-measures were deposited the Silurian beds had been slightly tilted at one end, namely, on the eastern side, and made to dip towards the west, and that their surface had suffered considerable denudation. The uppermost member of the Silurian formation, the Ludlow group, is only found on the western side of the main part of the coal-field. If we draw a nearly north and south line, starting from Ettingshall Park farm, running between Hurst Hill and Sedgley Beacon, and continue it down through Cradley to the south, we find that to the west of that line, wherever the Silurian rocks rise to the surface, namely, at Sedgley, at Turner's Hill, and the Lye Waste, they consist of the Ludlow or upper division; while all to the east of that line, wherever the Silurian rocks rise to the surface, or have been reached by shafts through the Coal-measures, they consist of the Dudley and Wenlock division of the upper Silurian series. The farther we go east, moreover, from this line, the more nearly do the Dudley limestones rise into proximity to the Coal-measures and to the surface, until at Walsall they crop broadly out, and the shales below them still rising gently to the

east, there comes out at Hay Head, near Barr, a lower limestone than has been seen in any other portion of the district.

A little to the east of that Barr limestone or of the beds which represent it, the May Hill or Llandovery sandstone, which lies next below it, makes its appearance, and would be much more largely exhibited if it were not immediately cut off by the boundary fault a little to the east of Shustoke Lodge, while near Hay Head it is concealed by a thin skirt of Coal-measures lying unconformably upon it, before both are thrown down by the boundary fault.

South of the true coal-field lies the Silurian district of the Lickey, where these same sandstones rise up from beneath the shales containing the representative of the Barr limestone. These also were elevated and denuded before the Coal-measure period, as we find thin Coal-measures resting directly upon them. It appears then that previous to the deposition of the Coal-measures there was here a broad and generally level plain of Silurian rocks (whether above or under water), the beds of which had a slight dip to the west, and cropped out successively towards the east, at the surface of the plain. The boundary of the Ludlow formation must have run somewhere along the line before mentioned, that of the Wenlock nearly along the line of the eastern boundary of the coal-field, while the Llandovery rocks spread some distance farther to the east. If any of the outcrops formed escarpments, they must have been low and gently sloping.

That this gradual rise to the east was continued yet further in that direction beyond the bounds of our district, is rendered probable by the fact of rocks still older than the Upper Silurian (perhaps older than any Silurian) appearing in the Warwickshire and Leicestershire coal-fields, with the Coal-measures resting directly upon them. It is, indeed, highly probable that all this tract of country, together with much of the adjacent district from Montgomeryshire to Leicestershire, became dry land after the close of the Silurian period, rising, perhaps, very slowly, and undergoing a very gradual and long-continued process of degradation as it passed through the destructive plane of the sea level; and that it remained above the waters during great part of the period marked by the formation of the Old red sandstone and Carboniferous limestone, and that accordingly those two rocks were never deposited upon it.

However that may be, we find that when the Coal-measures of South Staffordshire came to be formed, their earliest beds were deposited on a rather rough and cliffy (see p. 80, and Fig. 11), but generally horizontal surface, and that the dip of the Silurians, though still markedly to the west, was so slight that their beds could not at any one place have been seen sensibly to differ in inclination from the horizontal or nearly horizontal beds of the Coal-measures. We have already, in examining the base of the Coal-measures, seen the way in which at particular spots the lower beds of that formation filled up hollows in the Silurian rocks and obliterated their little pre-existing cliffs, and thus formed

a smooth floor for the deposition of the chief mass of the Coal-measure beds. (See p. 80.)

The Coal-measures, then, are distinctly unconformable to the Silurian rocks, but never so much so as that their respective angles of inclination are strikingly different at any one locality.

The practical importance of these apparently quite theoretical discussions will admit of a very apt illustration in this district. If the reader will look in the map of the district, at Walsall and its neighbourhood, he will see the Silurian limestones peeping out from under the Coal-measures here and there, and again becoming concealed by them, the Coal-measure boundary not at all strictly following the line of the limestones. Let us suppose the Coal-measure boundary to represent the outcrop of the Blue flats ironstone, which it really does very nearly, and let a sinking be made, say at the Butts, near Rushall, in which sinking, after passing through the Blue flats, the limestone was found at a certain distance, say 30 yards, below it; a person not understanding the fact of the unconformability of the two formations, might, after getting the Blue flats further east near Caudy-fields, sink down again for the limestone, and feel absolutely certain of reaching it at some depth not varying greatly from 30 yards. Instead of finding it, the pit would be sunk beyond the outcrop of the limestone altogether, as in the following diagram.

Fig. 17.

A. The first shaft.
1. Coal-measures.
2. Blue flats.
3. Lowest Coal-measures.
B. The second ditto.
4. Silurian shale.
5. Silurian limestone.

Now this very case absolutely occurred, although not exactly in the method above stated, and was described to me by Mr. Roberts, the mine agent at that very locality. It had always been a rather puzzling and incomprehensible occurrence to him, till I explained the way in which it had taken place.*

Having established the fact of the general unconformability between the Coal-measures and Silurian rocks, let us now examine the relations between the Coal-measures and the rocks above them, namely, the Permian and the New red sandstone.

1. As to the Permian.—We have already seen that in the southern part of the district we had nearly or quite a thousand feet of Coal-measures above the Thick coal, without including any Permian, or any other rock than the true Coal-measures. Now, in the sinkings at West Bromwich that took place a few years ago, several shafts passed down through a considerable thickness of Permian sandstone, and through a part of the Coal-measures

* This is one of the numerous minor difficulties in the way of intelligent practical men that I heard of while surveying this coal-field, that would have been no difficulties, had the knowledge of a little "practical geology" been attainable by them at an early period of life.

into the Thick coal. So far, however, from there being a thousand feet of Coal-measures between the bottom of the Permian and the Thick coal, there are not more than 520 feet at the Lewisham pit, 350 feet at the Lyng colliery, 330 feet at Messrs. Davis's pits at Spon-lane, and only 30 feet or 40 feet at the Heath pits of Lord Dartmouth. We have in these facts a clear case of decided unconformability between the Permian beds and the Coal-measures. We see that after the Coal-measures had been deposited they had suffered largely and very irregularly from denudation, several hundred feet of strata having been removed at one place which were left untouched at another, before the Permian beds were begun to be deposited on them. The belief of this denudation having taken place is confirmed by the appearance of angular and rounded fragments of Coal-measure rocks and pebbles of coal being found in the bottom beds of the Permian rocks at Quarry Hill near Halesowen, and at the Heath pits, West Bromwich (see Vertical Sections, Sheet 17, No. 17). We can hardly suppose this denudation to have taken place without a previous elevation and disturbance of the beds, although, as in the other case of the Silurian rocks, this elevation may have been so steady and equable that it did not cause the Coal-measures very sensibly to incline from a horizontal position.*

It is perhaps rash to generalise from the very scanty data we possess as to the precise relations between the Permian and Coal-measures. On so important a point, however, it is, I believe, a duty to state every opinion that may be fairly arrived at. I will therefore state, as my belief, that not only near West Bromwich, but *generally* in South Staffordshire and *the adjoining counties*, the Coal-measures suffered very greatly from denudation before the deposition of the Permian, and that the red sandstones of that formation were largely deposited in hollows and excavations worn in the Coal-measures by this denudation; and, moreover, that this excavation and denudation had in places proceeded to the length of being continued right through the Coal-measures down to the rocks below.

It may be useful, in order to arrive at a right understanding of this subject, if we discuss in detail the operations that were carried on at the celebrated Heath pits of Lord Dartmouth at West Bromwich. For this purpose we have the data given in Sir R. Murchison's Silurian System, and others partly collected by myself, but principally received from Mr. H. Johnson, Mining Surveyor, of Dudley. In the section published as No. 17, Sheet 17, of the Vertical sections, the actual shaft is drawn to scale, with the measures passed through, as given in the Silurian System, p. 476. On the left or west side of the shaft the section is copied from one lent by Mr. Johnson, which he compiled from the accounts of the men engaged in the sinking of the shaft, and corrected from his own measurements; and on the east side of the

* A dip of even 3° is often hardly perceptible either to the eye or to the clinometer, although it produces very large results if continued over a wide space. A bed dipping at 3° for the space of 3 miles will be 839 feet lower on the "deep" than it is on the "rise" side.

shaft are delineated to scale the headings or gateways that were driven in that direction, with the jackey pits and borings that were put up and down, together with a small ground plan both of the surface and the underground operations.

The following is a succinct account of these operations. In sinking the shaft they went down for 800 feet, through red standstones and other rocks certainly belonging to the Permian series. Below these, or at 804 feet from the surface of the ground, they entered the Coal-measures, and the following beds were passed through :—

	FT.	IN.
1. Grey clunch, with streak of coal -	2	0
2. Ditto, with batt at the bottom -	4	6
3. Grey clunch - - -	18	6
4. Grey fire-clay and ironstone - -	3	9
5. Light greenish grey and red rock, containing a thin streak of coal - -	21	0
6. Dark grey clunch and batt - -	4	6
7. Dark-coloured fire-clay - -	8	6
8. Coal - - - - -	0	6
9. Grey fire-clay - - - -	2	0
10. Coal - - - -	2	6
11. Grey fire-clay rock - - -	6	0
12. Coal - - - - -	9	0
13. Batt, gubbinstone, and table batt -	2	0
14. Grey clunch and lambstone - -	11	0
15. Coal, afterwards traced to Sulphur ? coal	2	0
16. White ironstone ground - -	4	0
17. Grey fire-clay and ironstone - -	4	0
18. Dark grey clunch and flattened concretions of ironstone - - -	14	0

No. 12, the nine-foot coal, was recognised as the bottom part (Slipper, and Sawyer, and Benches) of the Thick coal, with the Gubbinstone and Table batt thinner than usual below it. No. 15 was said to have been afterwards traced into the Sulphur coal ; but if No. 16 was rightly identified as the "White ironstone ground," this could not have been the case, as the Sulphur coal lies below the White (or New Mine) ironstone, and therefore No. 15 must have been the Heathen coal.

In examining the engraved Vertical Section, Sheet 17, No. 17, the reader must bear in mind, that while the measurements and position of the beds, as found in the pits, headings, and actual explorations are certainly accurate, the lines connecting these parts may not be exact representations of nature. They are probably only approximations to the truth, especially the shapes and positions of the coals to the west of the shaft, and the line marked "general boundary of the rock fault" on the east.

A "heading" was then driven in No. 12 for about 50 yards to the south-south-east, when the coal was found to thin out by the descent of its roof and come to nothing. A second heading was then driven 140 yards to the east-south-east, through Coal-measures lying in a very irregular condition, and at the end of that heading a bore hole was driven upwards, which at 12 or 15 feet above the heading passed through a three-foot coal, and was continued through dark clunch, for a total height of 100 feet, up into the "red rock." A third heading was then driven nearly parallel to this for about 35 yards, and at the end

of it a "jackey pit"* was sunk for 81 feet, through fireclay and sandstone, and from the bottom of that a boring was made for 180 feet lower. This bore hole was said to pass almost entirely through "Bavin measures," (by which Silurian shale is meant,) and these were said to be "very strong towards the bottom, in fact, defied all attempts to bore lower."† A fourth heading was then driven to the east by north for about 170 yards. This, after passing through the nine-foot coal before described, "went level away for 70 or 80 yards through an intermixture of black ground and binds. We then faced the Bavin measures, which seemed to pitch a little for 20 yards, and then ran level away to the back of the head." At the back of the head a two-inch bore hole was put up for 128 feet, which passed through about 17 feet of Bavin, and then dark clod for the remainder of the distance, above which they struck the "red rock," when so much water followed that the hole was obliged to be plugged up immediately. A two-inch bore hole was also put down here for 180 feet, passing through "Bavin" measures the whole way, and finally ended in what we considered to be (as in the case of the hole in the jackey pit) the limestone. Shells were found in great abundance in the Bavin measures of this head."‡ After making these fruitless explorations in search of the Thick coal to the east of the shaft, they came back to it, and went up to a higher level, and followed a little two-inch coal in No. 5 towards the west, and that shortly led them into the Thick coal.

Examining these facts by the light of the information gained in exploring the Baremoor colliery (see page) we shall, I think, have little doubt that the Thick coal is cut off at West Bromwich on its eastern side by a large "rock fault;" that beds of sandstone with fireclay and clunch come in, suddenly splitting up the Thick coal, and almost entirely occupying its place, and that the coal in No. 5, together with those numbered 8, 10, and 12, in the section (page) are all ends or detached parts of some of the beds of the Thick coal.

The general course of the boundary of this rock fault is nearly north and south, as it was found again, with Silurian shale beyond in the same heading, at the Lewisham pits near Virgin's End, one mile north of the Heath pits, likewise cutting out the Thick coal towards the east, and overhanging with a general inclination of about 22°.§ Similar facts with regard to the ending of the Thick coal at a depth of 200 yards against some "rock and rig," were observed in some pits east of Lyndon near Hall End colliery, where there are no "red rocks" or Permian beds over the Coal-measures at all.

The most curious fact, however, is, that there is a sudden rise of the Silurian rocks both at the Heath and the Lewisham pits, through the Coal-measures; and this I am inclined to believe is not in consequence of any fault, but is due to their having formed an old Silurian bank of rising ground during the Coal-measure period, and that the Coal-measures were deposited against that bank, its existence being favour-

* By a jackey pit is meant a small occasional shaft sunk in any part of the underground workings for a particular and temporary purpose.

† I believe this hard rock was the one met with while the "Silurian System" was passing through the press. It was, from the description, supposed by Sir R. I. Murchison to be trap. It probably, however, was the upper part of the Dudley limestone, or possibly the Barr limestone.

‡ MS. notes of the evidence given by the men who were engaged in these operations, lent to me by Mr. H. Johnson.

§ The general inclination of the sides of the rock fault at Baremoor colliery was much the same, varying from 18° to 25°.

able to the formation of sandstone and the accumulation of clay, but unfavourable to the formation of coal. The extension of this "rock fault" and old Silurian bank is at present uncertain; it appears, however, either that they extend continuously for three miles to the south of West Bromwich, or that they recur at that distance near Langley Green, as we shall see hereafter when describing the boundary faults.

We have in these facts, then, an instance of the unconformity of the Coal-measures both to the Silurian below and the Permian above; and it is probable that a little further east of the Heath pits the Coal-measures are entirely wanting, and the "red rocks" of the Permian formation rest directly on the shale or "bavin" of the Silurian formation. This would then be one of those cases where the denudation of the Coal-measures had proceeded the length of totally removing that entire series of rocks previously to the deposition of the Permian beds. The whole history of the Heath pits gives us a good example of the value of geological knowledge to the practical miner; 1st, assuring him of the general fact of the existence of coal beneath the "red rock" of the Permian and New red sandstone formations; 2nd, putting him on his guard as to the possibility of coming down to a spot where the coal had been removed by denudation, showing him what he might expect as *possible* as well as what was *probable*, and teaching him what to do in any case.

We have now to examine the original relations between the New red sandstone and the Permian. These two formations seem likewise to be unconformable to each other, but we cannot yet exactly ascertain either the amount or the precise method of this unconformability. The possibilities of the case are,—

1st. After the partial denudation of the Coal-measures the Permian rocks may have been deposited, not uniformly over the whole district, but in large patches here and there, filling up hollows, but leaving bare the higher spaces of older rock. On this surface the New red sandstone might be deposited, resting sometimes on the Permian, sometimes directly on the Coal-measures, or perhaps on still lower rocks.

2nd. The Permian, after having filled up and levelled the old hollows in the Coal-measures, was continued, as to its upper beds, over the whole district. In that case those upper beds must have been again more or less denuded, as we now find the New red sandstone resting sometimes directly on the Coal-measures without the intervention of any Permian rock whatever.

This is the case at Brereton near Rugeley, where they have sunk in several pits through the quartzose gravel or conglomerates of the New red down into the Coal-measures, the two lying distinctly in an unconformable position, the coals cropping gently up into the base of the New red.

After attaining the New red sandstone there appears no further occurrence of unconformability, the beds appearing to lie with perfect parallelism and regularity through the red sandstones and gypsiferous marls up to the Lias of Needwood Forest.

CHAPTER X.

Position* and Lie of the Rocks.

General Description.

The South Staffordshire coal-field seems like an island of Palæozoic rocks rising up through the secondary New red sandstone plain of the centre of England. These rocks appear at the surface partly in consequence of their being elevated to a higher level than the Palæozoic rocks immediately adjacent to them, which are still covered by the New red sandstone, and partly in consequence of the New red sandstone, which once covered them also, having been removed by denudation.

The general form of the Palæozoic district is that of a rather rude and irregular spindle-shaped band slightly bent so as to have both its sides convex to the west, and terminating in a point both to the north and to the south.

These points are at Barnt Green, which forms the southern termination of the Lower Lickey range, and at "Brereton Coal Pits," near Rugeley. They are very nearly 26 miles apart, and bear about N. 7° E. and S. 7° W.† from each other. Neither this line, however, nor its bearing, is of any importance, or requires further notice in the description of the district.

There are, however, two lines which can be drawn within the Palæozoic area which are worthy of notice in themselves, and indicate bearings that are very important, giving us, indeed, the key to the structure of the district.

The first of these lines runs from Barnt Green to the termination of the Sedgley Silurian ground near Parkfield school, south of Wolverhampton. This line is 14½ miles long, and bears as nearly as possible N. 22° W., and S. 22° E.

The second line starts from the south-west angle of the coal-field near Pedmore, and terminates at the Brereton coal-pits before mentioned. It is 22 miles long, and bears N. 23° or 24° E. and S. 23° or 24° W.

These two lines intersect in the town of Dudley, where they cross each other at angles of about 45° and 135°. A line bisecting the angle of 45° would run as nearly as possible north and south. A line bisecting the angle of 135° would be as nearly as possible east and west.

The first line runs along the ridge of the Lower Lickey, and is parallel to the general direction of the boundaries of the southern

* By "position" is meant the place in or under which such and such rocks will be found, their depth from the surface, &c.; and by their "lie" is meant the form and manner of their occurrence, their angle of dip, their faults, &c.

† True bearings are always meant, unless when otherwise expressed.

part of the coal-field, to the Russell's Hall fault, to the greatest surface extension of the Rowley basalt, and to the general direction of the Dudley and Sedgley anticlinal.

The second line forms the axis of the Netherton anticlinal, runs nearly parallel to the Dudley Port Trough faults, to the outcrop of all the beds (both Coal-measures and Silurian), along the eastern margin of the district from West Bromwich to the Brown Hills, to the outcrop of the beds about Wyrley and Essington, to the western boundary fault north of Wolverhampton, and to the general direction of the northern part of the coal-field from Dudley northwards.

These two lines then point out to us the two directions along which the disturbing forces acted that have produced the principal inclinations of the rocks, and the principal fractures that traverse them. It may at once be seen by inspection of the maps that all the lines of outcrop and all the faults of any importance either run parallel to one of these lines of bearing or parallel to the lines which are their resultants, or those which lie half-way between them. That is to say, all the features mentioned above strike—

either N.N.W. and S.S.E.,
N.N.E. and S.S.W.,
N. and S.,
or E. and W.

All faults and all strikes that do not coincide very closely with one of those four lines of bearing are either small and unimportant, or occupy spaces that may be described as merely the connecting links where the one line of bearing is passing into the other.

Having thus sketched the outline of the framework of the district, let us commence our description of the lie of the beds at its southern portion.

The Permian rocks stretch in nearly horizontal and continuous sheets through the Clent Hills and the high ground of Hunnington and Romsley, Frankley Hill and Kitwell to Bartley Green. These beds dip with a very gentle inclination to the south. They are cut off both to the west and to the east by faults which afterwards form the boundary faults of the coal-field.

Towards the south these rocks have been largely denuded, especially in the middle portion south of Frankley Hill, where the surface of the ground dips more rapidly than the dip of the beds, and the rocks below the Permian are consequently exposed by the denudation. We find these rocks to consist of altered Llandovery sandstone and lower Wenlock shale and limestone, forming the broken anticlinal of the Lower Lickey, with a little unconformable deposit of Coal-measures on each side of it.

The Permian rocks and the beds below them soon, however, become concealed, both to the south-east, south, and south-west,

under the New red sandstone, either in consequence of their continued dip, or from their being suddenly thrown down by downcast faults in those directions.

If now we return to the high ground stretching through the Clent Hills and Frankley Hill, and descend its northern slopes towards Halesowen, we shall see that the beds of Permian rise gently to the north, and that at the foot of the slope the Coal-measures appear from underneath them. These Coal-measures consist, first of thin grey shales and clays, then of the Halesowen sandstones, and then of red clays, each successively rising out to the surface towards the north as we descend into the valley of the Stour.

We are here fairly within the coal-field which thence runs off continuously to the northward, or a little east of north, between its boundary faults, till we arrive at Hednesford and Brereton. The boundary faults are sometimes single large downthrows bringing the New red sandstone into direct contact with the Coal-measures, and are sometimes more complex, allowing of the appearance of more or less of the Permian rocks between the Coal-measures and New red sandstone.

At Hednesford and Brereton the two boundary faults seemingly run off into the New red sandstone, and over the space between them the Coal-measures are apparently covered by an overlap of the New red sandstone resting unconformably upon them. It is probable, however, that the Coal-measures are here, either let down by faults, or largely eroded under the New red, which formation probably thickens much more rapidly to the north than would be supposed by the mere inclination of the beds.

The coal-field then is a narrow plateau of Coal-measures bounded both on the E. and the W. by downcast faults, covered on the north by unconformable New red sandstone, and dipping on the south under apparently conformable Permian rocks.

The coal-field itself may be divided into two parts, each of which may be again subdivided into two.

The principal line of division in the coal-field is that which runs from Parkfield a little south of Wolverhampton, through Sedgley, Dudley, and Rowley, to the Leasowes. This line forms a broad anticlinal ridge from Parkfield to Dudley, round which ridge the coals all crop out, and on which the Silurian rocks rise to the surface at four places. Three of these, namely, Dudley Castle Hill, the Wren's Nest, and Hurst Hill form long oval elevations of the Dudley limestone, the axes of which run north and south, with the beds curving round at very high angles, but more broken by transverse dislocations than they seem to be at first sight. The fourth, namely, the Sedgley ridge, is a broader and more irregular synclinal flexure, the axis of which is likewise north and south, and which is also broken by faults.

South of Dudley this anticlinal form of the beds ceases, but the line of division is continued partly by the surface feature of the Basaltic hills and a steep western slope that runs from them to the south, but chiefly by a line of fault below the surface, having a great downthrow to the west-south-west, which we may distinguish as the Russell's Hall fault. To the south of the Basaltic range this line of fault appears as if again about to take an anticlinal form, since the Coal-measures rise sharply up to it from the west-south-west, if not from both sides. The line of division is then lost for a space, but re-appears again in almost exactly the same line of bearing in the narrow and broken anticlinal ridge of the Lower Lickey Hills (Rubury Hill and the Bilberry Hills).

We may speak of the part of the coal-field lying west of the line above indicated as the South-Western portion of the coal-field. It is subdivided into two by the Netherton anticlinal, a line 3 miles long running north-north-east and south-south-west, with the Silurian showing itself in its southern portion, and the coals cropping out on both its flanks and round both terminations.

The basin between the Netherton anticlinal and the Russell's Hall fault we may call the Cradley Basin. This basin seems to be comparatively free from faults, and except those that bound it has certainly no dislocations of great magnitude.

The basin lying between the Netherton anticlinal, Kingswinford, and Gornal we may call the Pensnett basin. This is traversed by a number of large and important faults that will be described more in detail presently.

Where the Netherton anticlinal ceases towards the north, there is a trough or hollow in the beds, nearly a mile wide, between it and Dudley, forming a channel connecting the Cradley and Pensnett basins. We will speak of this as the Old Buffery Trough, from the name of some ironworks situated in it.

The other principal part of the coal-field lies to the east and north of the main line of division before described. It is subdivided into two by the Great Bentley fault, which a little north of the latitude of Walsall runs across the coal-field from east to west, with a downcast of 360 feet (120 yards) to the north.

South of the Great Bentley fault lies the central and south-eastern part of the coal-field. The central is the part between the Dudley and Sedgley anticlinal and the Walsall Silurian district, both on the east and west side of which the Coal-measures successively crop out, and allow the Silurian rocks to appear from underneath them. They also rise, but much more gently, towards the north, the Thick coal, Heathen coal, and New Mine coal cropping out one after another in that direction, and the beds below them being at a very slight depth when they range up to the Great Bentley fault. This central district is traversed by many east and west faults, all having their greatest throw in the middle of their range, and all being downcasts to the south till we

come to the space south of Tipton occupied by the Dudley Port Trough. The pair of faults forming the Dudley Port Trough run parallel to, and almost in the same line with, the Netherton anticlinal. They tend, however, to produce a synclinal rather than an anticlinal effect, and the faults on each side of them aid that effect, since their downthrow is always towards the Trough. The faults running parallel to the Trough which strike from the northern flank of the Rowley Hills are mostly upthrows to the south-east till we approach the Brades, when they again have a southerly downthrow.

Beyond these the Coal-measures stretch into what we may call the south-eastern end of the central district, in which the beds lie nearly flat, as about Titford and Causeway Green, between the Rowley Hills and the eastern Boundary fault.

North of the Great Bentley fault lies the northern portion of the coal-field, in which the dip of the measures is at first steadily from east to west, at a mean angle of about 3°, gradually curving round till it dips west-north-west, and then apparently north-west at the same low angle, over Cannock Chase up towards Brereton. In the Old Park of Beaudesert, however, they appear to become first quite horizontal, and farther on at Brereton they are said to dip gently to the south-east, and to rise towards the north-west and crop up into the New red sandstone that lies upon them.

Many faults running chiefly east and west traverse the northern part of the coal-field, especially the part of it between the Great Bentley fault and Cannock Chase.

Trough Faults.—Besides the faults which have already been mentioned by name, there exists many others, some of which have been alluded to, in all parts of the coal-field. Their description must be left till we speak of them in detail, but it will be well first of all to call attention to those among them which dominate over the rest, and seem to bear to them a relation analogous to that which the keystone bears to the arch.

These are the Trough faults, of which we may enumerate six.

Two of these are in the Pensnett Basin, namely, the well-known Brierley Hill Trough, which runs nearly due east and west, and the less marked Tansy Green Trough, which, likewise, has a general east and west extension.

The central district has only one, but that is the largest and best marked of all, namely, the Dudley Port Trough, which runs nearly north-north-east for three miles, and then gradually curving round seems to merge into the system of east and west faults that traverse that portion of the coal-field.

The Great Bentley fault is itself the southern side of a trough, though of an unequal and imperfect character, since the amount of the upthrow of the corresponding fault on the northern side is only about one-fifth or one-sixth of the downthrow of the Great Bentley fault itself.

Besides these four, there are two very well marked, although only small troughs, which are known in the northern part of the field. The one is that of the High Bridge in the Pelsall district, and the other that which we may call the Rising Sun Trough, down the centre of which Watling Street runs from the old inn called the Rising Sun to the eastern boundary fault.

CHAPTER XI.

POSITION AND LIE OF THE ROCKS.

Detailed Description.

THE preceding chapter is intended for the use of the general geological reader, who wishes to gain merely a general notion of the structure of the district; read with the maps before him it may be sufficient for his purpose.

In this chapter it is intended to describe in a little more detail the features there sketched out, and to give some of the data on which the descriptions are founded.

We will first of all describe the main line of division before mentioned in Chapter X,. commencing with the northern part of it, namely, the Dudley and Sedgley anticlinal.

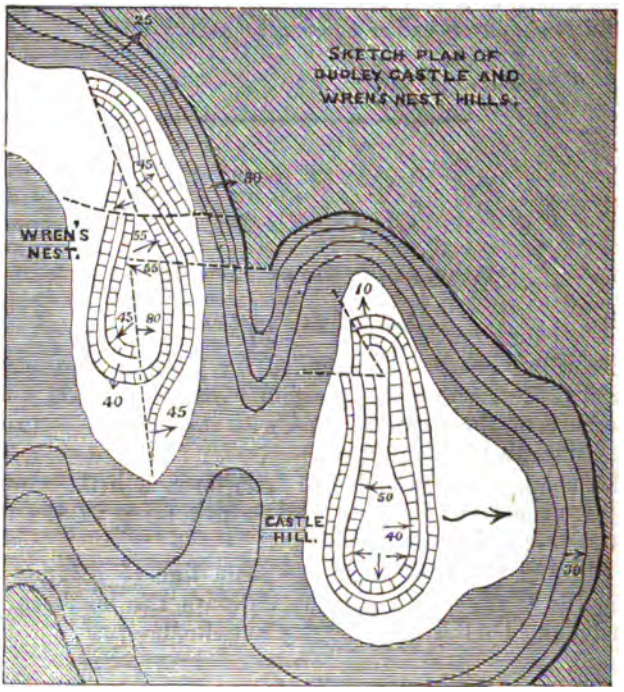
MAIN LINE OF DIVISION OF THE COAL-FIELD.

The Dudley and Sedgley anticlinal is not a simple one, but very complex. There is one general broadish area of elevation which may be said to be defined by the outcrop of the Thick coal. Ranged, however, on this wider and gently-elevated region there are three smaller areas that have each suffered from a maximum intensity of elevating force, namely, Dudley Castle Hill, the Wren's Nest, and the Sedgley district, including Hurst Hill. The axes of these three areas of maximum disturbance do not run parallel to the general axis of the elevated tract, but cross it very obliquely, running nearly true north and south. They would thus appear to be the result of the nearly equal action of the two prevailing lines of disturbing force before mentioned, as they run in a direction equidistant between them.

Dudley Castle Hill.—At Dudley Castle Hill the two bands of limestone rise boldly out on the south, at angles varying from 25° to 30°, curve round with great symmetry and regularity on each side, and stretch off to the north in a narrow ridge, the sides of which dip east and west respectively from its central portion, see Fig. 18. As they run north the inclination of the beds increases to 50°, and the two pieces of the lower limestone nearly meet each other on the crest of the ridge. On the east side the limestones begin at Shirts Mill to curve regularly round towards the north-west, dipping north-east, and then towards the west, dipping north at 10°, but are then suddenly cut off by a fault. The limestones on the west side are cut off by a fault

opposite Shirts Mill, and in the gap between these two ends a piece of the upper limestone only is seen at the surface of the ground, dipping about west-south-west.

Fig. 18.



Scale, 2 inches to a mile.

Dark part is Coal-measure ground, with dark lines for coal crops; the part obliquely shaded being above the Thick coal, that horizontally shaded being below it. Light part Silurian ground, with the limestones. Dotted lines are faults.

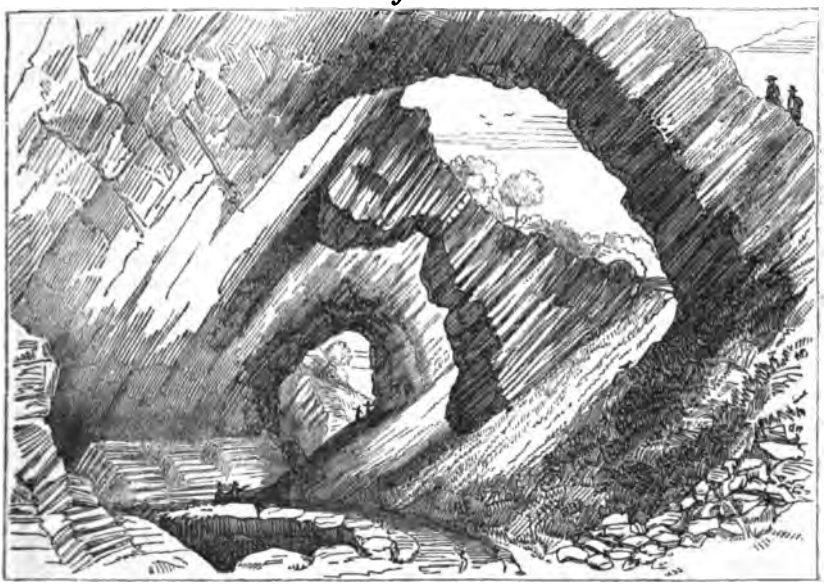
On the east side of the Castle Hill, between it and the Tipton road, the beds of limestone, after dipping from the hill for some distance, are found in the under-ground workings to flatten, and afterwards rise again towards the east, so that where the words "Castle-foot pottery" stand in the Ordnance map, east of the Tipton road, the limestone is reached by a shaft at the depth of only 52 yards (156 feet). From this point it again dips towards the east, at such an angle that in the space of 90 yards due east it becomes 112 yards deeps (336 feet).*

Wren's Nest Hill.—The Wren's Nest Hill is similar in general structure to the Castle Hill, but differs from it in some of its details. Like the Castle Hill, its general form is that of an oblong dome-shaped elevation, with a central nucleus of lower shale, on which repose the limestones, dipping every way at considerable angles from the centre of the hill. On the south-west side of the hill the beds curve round very symmetrically, dipping west, south-west, and south, at an angle of about 40°. Similarly on the north-east side the two limestones are symmetrically curved, dipping east and north-east, and finally almost

* This gives us a dip of 60 yards in 90 = 32°.

north at about 45°. Along the east and south-east sides of the hill, however, the inclination of the beds is much steeper, rising to 50°, 60°, and in one part upwards of 80°. At the south-east corner the beds, instead of bending regularly round, are broken through by a fault, so that the end of the upper limestone on the west of the fault is made to abut against the base of the lower limestone on the east side of it. The lower limestone of the east side is itself cut off by the fault a little farther south, but the upper limestone ranges some distance to the south alongside of the fault till, being finally traversed by it at a very oblique angle, it also disappears. The course of the fault towards the north may be traced a little way by the ending of the lower limestone on its west side, but it very likely runs up to the centre of the hill. From this spot a fault runs due east, cutting through the beds on that side of the hill, and shifting their outcrop 30 yards, so that the upper limestone on the south side of it is made very nearly to face the lower limestone on the north ; from which it follows that this must be a very considerable downcast to the south, the beds north of it rising at an angle of 55°, those to the south at one of 80°.

Fig. 19.



Caverns, West Side of Wren's Nest.

About 250 yards north of this another east and west fault cuts right across the ridge, fracturing the beds on the east side, and entirely cutting off those on the west.* From the centre of the ridge where it is traversed by this fault another is supposed to spring, running north-west, in order to account for the sudden ending of the two limestones in that direction as they curve round from the north-east side of the hill.

* It is worthy of remark that these faults in the Wren's Nest and the other Silurian elevations do not appear to affect the Coal-measures, although it is clear that these dome-shaped elevations did not take place till after the Coal-measures were deposited. It is plain, therefore, that the cracks and fissures of the dome-shaped elevations are strictly local, or have not much longitudinal extension.

Between these two last faults, on the north-west side of the ridge, a piece of the upper limestone only reaches the surface, just as a similar piece did between the two faults on the north-west end of the Castle Hill.

In the valley between the Wren's Nest and the Castle Hill repose the lower beds of the Coal-measures, the Bottom coal running some distance into it, both from the north and south ends of it.

Coal-measures likewise stretch between the Wren's Nest and the Sedgley Silurian district, but these are only the sandstones forming the base of the formation, and *they* lie only on the higher parts of the ground, the bottom of the valley north-west of the Wren's Nest showing Silurian shale at the surface.

The Sedgley District is rather a complicated one.

Hurst Hill.—On the east side of it is Hurst Hill, where the Wenlock and Dudley limestones rise into a long oval anticlinal ridge, like those of the Wren's Nest and Castle Hill, but not so perfect. At the southern end the two limestones bend round and abut against the base of a piece of the upper limestone, a fault running between the two; this piece of the upper limestone must be cut off each way by faults, and a fault dropping down to the west runs along the whole of the remainder of that side of the ridge, preventing the appearance of the limestones. On the eastern side the beds strike north, dipping east at a high angle, they are broken through by a small east and west fault just south of the Cann Lane road, but from that spot strike still north till they curve round the northern end of the ridge, and dip in that direction.

They have been followed under ground north of the hill for 200 or 300 yards, dipping generally north at about 30°, and ending towards the west against a fault which runs about north-north-west, and which must be a downcast to the west.

Sedgley Beacon.—West of Hurst Hill is a rising ground formed of the Ludlow rocks, containing the band of limestone before described as the Aymestry and Sedgley limestone. These at first dip west at an angle of 10° to 20°, forming a pretty bold escarpment towards the east known as Sedgley Beacon Hill. The limestone, however, soon rises again to the west, and forms a cap to the high ground south of Sedgley, and after undulating a little in various directions, finally crops out on the west side of the hill, dipping east at 10°. North of Sedgley this cap does not appear, the Silurian beds forming a basin instead of a cap, and only cropping out on the west side of the Wolverhampton road, where they dip pretty regularly to the east at an angle of 20° for about half a mile. They then appear to curl over for a short space, and dip north-west at 35°, but I believe this is only a local flexure, and that the limestone beds curve round from this point to meet those of the Beacon Hill quarry. About one third of a mile north of that, however, the limestone again appears suddenly at the surface, dipping north-east at 60°, its northern end curving round till it dips north and north-north-west, at 15° and 20°, and then suddenly ending. The faults drawn on the map are the most obvious explanation of this peculiar position of the rocks, though with the exception of the one on the west side of Hurst Hill, they are all put in hypothetically. In the hollow of the Silurian rocks north of Sedgley the sandstones forming the base of the Coal-measures again occur, as shown on the map. About half a mile south of Sedgley the Silurian rocks must be cut off by an east and west fault, a downcast to the south, which brings in the Coal-measure sandstone on their level.

Turner's Hill.—These lower sandstones spread over the ground from Upper Gornal, by Ellows Hall, to Lower Gornal, undulating in various

directions, and at Turner's Hill, west of Lower Gornal, a patch of the Silurian with a band of Aymestry limestone again makes its appearance from under them. There is, however, but one small quarry in it, and the exact details of the structure of the country just hereabouts are very obscure.

Coal, supposed to be part of the Thick coal, has been found and partially worked in the valley, which runs from the west side of Sedgley down by Cotwall End. It was, however, much broken and disturbed, but was said to dip generally to the west, and frequently at very high angles.

At Sedgley Hall farm a trial pit was sunk in 1828, in which they passed through 120 feet of "red croprash rock and marl," under which were 200 feet of Coal-measures, and then the Thick coal dipping west at an angle of 12°. As there is no sign of the Thick coal cropping out between this spot and the Silurian ridge, there must be a fault between, which makes it probable that a fault forms the west boundary of the whole of the Sedgley Silurian district.

Outcrop of the Coals round the Dudley and Sedgley anticlinal.—We will now briefly trace the outcrop of the coals round this singularly dislocated district of elevation. Beginning on the south of the town of Dudley, the Thick coal and the beds just above and below it crop regularly out, dipping south at an angle of about 25°. The crop of the Thick coal may be traced very easily, partly by the old, partly by the present workings across Dixon's Green, and a little north-west of the Freebodies to Burnt Tree, when it dips east at 30°, and thence curving round the Silurian tract of the Castle Hill to the angle between it and the Wren's Nest. Along the north-east flank of the Wren's Nest the Thick coal is nearly vertical, and was worked in an open quarry in the years 1849 and 1850.*

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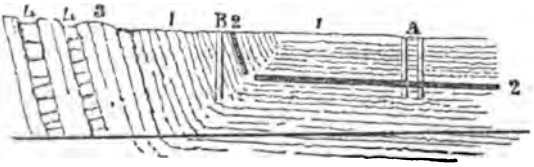
* As a good illustration of the very careless and ignorant manner in which the South Staffordshire coal-field has been worked, I will describe the way in which this vertical piece of coal was discovered. A little to the east of it the Thick coal had been worked continuously in a nearly horizontal position at a depth of about 70 or 80 yards, as at A, Fig. 20. The workings were continued towards the Wren's Nest till the coal ended against a fault or supposed fault, or at all events, some "troubled ground." A shaft, B, Fig. 20, was then sunk from the surface, about 30 or 40 yards to the west of this supposed fault, in search of the coal. No notice could have been taken, in sinking this shaft, of the angle at which the beds inclined, and after being continued for more than 70 yards it was abandoned. In fact it must have been sunk the whole distance nearly along the same bed in which it was begun, the beds being nearly vertical, but that was not observed, or not understood, neither were the beds below the Thick coal recognized. The lease of the land was on the point of being given up by the gentlemen who held it, when, a few feet of rubbish being accidentally removed from the surface at a particular spot, the end of the Thick coal was uncovered and of course worked. Even then, however, the ground bailiff, whom I met on the spot, and who had charge of all the mining operations, seemed scarcely to understand that this was merely a piece of the Thick coal bent up into a nearly vertical position, and broken off the horizontal portion below, as shown in diagram, Fig. 20.

Fig. 20.



A. The old shafts.
B. The new shaft sunk in search of the coal.
1. Coal-measures.
2. The Thick coal.
3. Silurian shale.
4. The Limestones of the Wren's Nest hill.

The coal strikes regularly from this spot to the Foxyards, where it flattens very rapidly to a nearly horizontal position.* It was formerly worked here also in an open quarry. Hence, after bending a little into the hollow between the Wren's Nest and Hurst Hill, the crop of the Thick coal runs along Ettingshall lane nearly up to Monmore Green.

A little south of Catchem's Corner it is broken through by the branches of the Great Lanesfield fault, which traverse likewise the lower beds to the west of it. Here, between the Ettingshall Park farm and Monmore Green, there is a very broken and disturbed district of Coal-measures. It appears that a rude anticlinal curve runs north from Hurst Hill by Ettingshall Park farm, the Parkfield furnace, and the Rough Hills colliery. The New Mine, Fire-clay, and Bottom coals, after rising to the west, flatten, curve round, and dip again to the west; and a fault running north and south by the Wolverhampton furnaces, has a downcast to the west of about 150 feet, and brings in a good sized patch of the Thick coal in that direction, which dips north-west and west at an angle of 30° towards the red rock of the Permian formation. South of this, on the west side of the Parkfield colliery, the Coal-measures are completely smashed up by faults, and contorted in so violent a manner that, as I was informed by Mr. Smith of the Priory, one shaft passed through the Blue-flats ironstone three several times, first meeting it with the top bed uppermost, but dipping at a very high angle, then with the bottom part uppermost, also at a high angle, and then again with the top side uppermost and nearly horizontal, the beds being curved into the form of an S. It was quite impossible to represent on the very inefficient scale of the Ordnance map anything at all approaching to the complicated faults and contortions of this piece of ground; but a few of the principal have been drawn with a tolerable approach to accuracy. They show that the action of the disturbing forces did not end merely in producing the Silurian elevations lately described, but was continued into the Coal-measures to the northward, and may have extended still farther for an unknown distance, producing fractures and dislocations in rocks now buried under the Permian and New red standstone rocks on the north-west.

Returning now to the south of Dudley, the outcrop of the Thick coal may be traced by the old workings along the south-west side of the town up to Shaver's End and Russell's Hall. It dips at a gentle angle to the south-west, not exceeding in any case 20°, and rarely so much as 10°, and as the ground likewise slopes rapidly in that direction, the Thick coal does not at first acquire any great depth, and its outcrop is deeply waved and indented by the valleys and hollows of the surface.

Thus the little valley north of Russell's Hall completely cuts down through the Thick coal into the lower measures. As the ground on the opposite side of the valley, however, called Dipdale Bank, rises to a sufficient height, it again brought in a large patch of Thick coal that extended nearly up to Gornal, where the ground slopes the other way. This piece of Thick coal being in no place more than 20 yards deep, has long been worked out.

These men have a fixed idea *that coal grows*, that it is still growing and forming in the earth, and that not only the coals and ironstones grow, but that the *faults grow likewise*; it is not possible, therefore, that they can have any clear ideas of their work, or be able to adapt it to any unusual circumstances.

* At the Foxyards a ground bailiff informed me that the Thick coal there was not the same as the Thick coal just mentioned, his only reason being that a parting of shale was a foot thicker in one place than in the other; he said there must be a fault between them on that account!

The Russell's Hall fault.—On the south-west side of this indented outcrop* of coal runs the long Russell's Hall fault, which here throws down the Thick coal and other measures 120 feet to the south-west. Owing to a local flexure and rise of the beds, however, the Thick coal again crops out round Gornal Wood on the downthrow side of the fault.

The Russell's Hall fault running on the south-south-west side of the Sedgley and Dudley ridge, is continued to the south-east along the south-west flank of the Rowley Hills. It holds its course very regularly towards the south-east, its "throw" increasing as we proceed to the southward, up to 150, 180, and 240 feet, and eventually, near Rowley Regis, it has a downthrow to the westward of upwards of 400 feet. Beyond this its details are not accurately known, but at Coombs Wood it was partly proved by Mr. W. Mathews, and it seemed as if the fault were there passing into a very sharp anticlinal curve, as he found some Thick coal on the west side of it only 16 yards from the surface, and dipping at a high angle to the west, in which direction it acquires a depth of 750 feet in the space of a mile. On the east of the fault line it is known also to be 570 feet deep at a similar distance.

Near the foot of Mucklow Hill, a disturbance, probably due to this fault, may be seen in the Coal-measure sandstones, which dip 3° to the east on one side of it, and 30° or 40° to the south-west on the other. As the beds seem nearly, if not quite similar, it is probable that here also it is rather a rude anticlinal than a clean-cut fracture or fault.

The Rowley Basalt.—It is remarkable, that where the Sedgley and Dudley anticlinal ends, the mass of the erupted basalt of Rowley begins, and that hereabouts the Russell's Hall fault has its greatest amount of "throw," and is most of an actual fracture, while a mile south of the Rowley basalt the dislocation appears to be on the point of passing again into an anticlinal ridge. This almost looks as if there would have been a continuous anticlinal elevation all the way from Sedgley to the south end of the Lickey had it not been for the eruption of the Rowley rag. If the eruption of the Rowley basalt could be shown to have been subsequent to the formation of the whole Coal-measures, and contemporary with the fractures and dislocations of the coal-field, it might readily be accepted as a *vera causa* for the gap between the two anticlinals mentioned above. We should then suppose that the strain acting on the beds was relieved at one point by the actual outburst of trap, while in others it resulted in the uplifting and protrusion of the inferior rocks.

I believe, however, that this apparent connexion between the occurrence of the Rowley basalt and the dislocations and lie of the Coal-measures is an apparent and accidental one only. The change from a bold anticlinal to a mere depression, with a fault on one side of it, I think is due to the fact of the Dudley Port Trough faults cutting across the course of the anticlinal. These faults actually dislocate the Rowley basalt, which must, therefore, have been solid at the time of their formation.

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* Mr. J. Kenyon Blackwell was kind enough to accompany me in tracing the crop of the Thick coal hereabouts, with his ground bailiff, Mr. Waterfield. The outcrop of the coal was perfectly well marked by the occurrence, at the surface of the ground of fragments of "shattery." This is the local name for a well-known indurated shale, streaked red and green, and baked almost into jasper. After extracting the coal, the fragments of coal and shale are piled up in the hollows to afford a partial support to the roof. This mass of fragments is called the "gob," and in shallow excavations, where the air and water from the surface find ready access, it frequently takes fire, and burns for a very considerable time with a slow combustion. Just at the west entrance of the town of Dudley, in a cutting of the road, smoke and steam may often be seen in damp weather rising through the joints and cracks of a sandstone rock, from the combustion of the "Thick-coal gob" below.

It is, however, quite possible that the existence of the Rowley basalt and of the net work of dykes and veins of trap below it, was one of the reasons why the Dudley and Sedgley anticlinal was not continued to the south-south-east. The rocks beneath the basalt may be so bound and laced together by this net work of trappean braces, that the forces of elevation, whatever they were, were unequal to the task of bending them up into symmetrical curves and dome-shaped elevations like those of the Castle Hill and the Wren's Nest, &c., and left them, therefore, comparatively undisturbed, except by fractures and dislocations, some of which we can trace, but of which many more probably exist than we are yet aware of.

I believe, therefore, that here, as elsewhere, wherever I have had an opportunity of making accurate observations, the mere intrusion or outburst of igneous rock has had little or no immediate connexion with the dislocations or elevations of the rock.

Following the direction of the line of the Russell's Hall fault south of Mucklow Hill, we find an interval of several miles in which no observations can be made.

What may be the position of the Coal-measures below the Permian beds of Frankley Hill we of course have no means of ascertaining; but on the south side of that ridge a few Coal-measures with a little coal showed themselves, on each side of the quartz range of the Lickey, in a nearly horizontal position. These beds may stretch continuously and horizontally under the Permian, from the valley south of Halesowen, and become exposed at the Lickey by simple denudation, in which case they are probably very high Coal-measures, or they may be the lowest Coal-measures brought up either by the rise of the beds or by dislocations concealed under Frankley Hill.

The Lickey Hill anticlinal.—If, however, we follow the direction of the southern half of the Russell's Hall fault, namely, about south-south-east, we shall strike in about 4 miles on the linear elevation of the Lickey quartz rock, which likewise has the character of a broken anticlinal. This fault, therefore, connects, if only in a vague way, the two *anticlinal ridges* of which the axes both run north-north-west and south-south-east, that, namely, of Sedgley and Dudley with that of the Lower Lickey.

The quartz rock of the Lickey is greatly broken and fractured, and in some cases violently contorted. At the northern end, about Holly and Rubury Hills, and by the New Road, it dips easterly at from 10° to 20°. Near the old Rose and Crown it dips west at 35°. In the quarry opposite the Reservoir it is violently contorted. At the south end limestone was formerly got, and there seem to be some softer shaly beds thereabout, which are doubtless the bottom beds of the Wenlock shale. It is believed that the eastern boundary of the quartz ridge south of the Colmers is a fault, with a downthrow to the east. North of the Colmers soft shaly beds, with calcareous bands and Silurian fossils, have been got on each side of the ridge, just underlying the Coal-measures.

We have doubtless here the very same beds that occur about Shustoke Lodge and near Hay Head, namely, the Llandovery sandstone locally altered into quartz rock and thrown into a small anticlinal ridge, with the bottom beds of the Wenlock shale and calcareous bands representing the Barr limestone covered unconformably by thin skirtings of Coal-measures. The Permian beds near Barr seem to be brought in solely by a fault, though perhaps even that is doubtful, while at the Lickey there is no occasion for any such supposition, since they seem simply to have covered up all the other rocks unconformably,

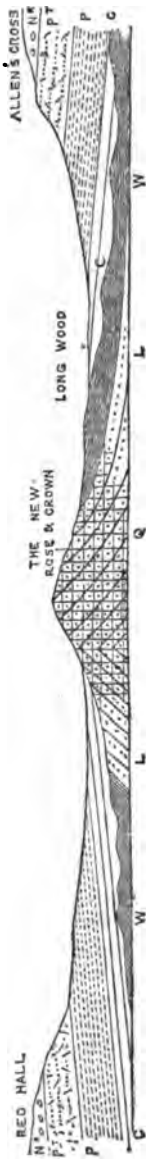
and to be now partly removed from off a certain space by simple denudation.*

The following diagram, Fig. 21, represents the probable relations of these rocks.

Fig 21.

Fig. 21.

Diagrammatic Section across the Lickey, through the Long Wood, and by the new Rose and Crown.



Scale, horizontal, 2 miles to 1 inch.

Nr New red sandstone.
Pt Permian trappean breccia.
P Permian red sandstones and clays.
C Coal-measures.
W Wenlock shale
L Llandovery sandstone converted into Q. quartz rock over a certain space in the centre.

* Professor Ramsay, however, informs me that subsequent careful examination made by himself led him to the conclusion that the ridge of the Lickey, formed of quartz rock, was everywhere bounded by a fault, as shown in the later editions of the maps. My own notion still is that the appearances may be accounted for by the overlap of the different subdivisions of the Red rocks among themselves, and their total unconformity as a whole to the rocks below.

THE SOUTH-WESTERN PART OF THE COAL-FIELD.

Having described the line of division which separates the south-western from the central portion of the coal-field, let us now examine the lie of the rocks in that south-western portion.

It was shown in the last chapter that this was partly separated into two basins by the Netherton anticlinal.

The Netherton anticlinal.—A little east of the village called the Lye, near Stourbridge, is found a protruding mass of Ludlow shale, with a band of limestone like that before noticed at Turner's Hill and Sedgley. It dips east at 40°, but after running north of the road for almost a quarter of a mile, it suddenly ends, being probably cut off by a fault. Immediately south of the road it terminates somewhat in the same way.

In the cutting of the road the Silurian shale may be seen dipping east at 40° for about 30 yards above the limestone; there are then 9 yards of Coal-measure sandstone, with ironstone balls, dipping in the same way, and 100 yards east of that the bottom beds of the Thick coal may be seen dipping west at 65°, or towards the limestone. The Thick coal must, therefore, be reversed, or bottom upwards. In the Hays coal-pits, just east of this, the Thick coal is found greatly broken and disturbed, dipping generally east, at a high angle, and then suddenly assuming a nearly horizontal position, in which it continues some hundred yards to the eastward.*

From the Hays the crop of the Thick coal may be traced about a quarter of a mile to the south-south-west, when it curves suddenly to the west, dipping south at a considerable angle. On the other side of the Lye the Thick coal comes in again dipping west, and on this side the outcrop of the coal may be traced some distance to the south-west, when it appears suddenly to come to an end.

In the brook between these two terminations of the Thick coal some Coal-measures may be seen dipping to the south, it is, therefore, very probable that the apparent termination of the Thick coal outcrop to the south-west of the Lye is due merely to a sharp flexure and change in its strike, and that it turns suddenly to the eastward and joins that coming towards it from the other side of the anticlinal. The Netherton anticlinal will in this way terminate to the south with a regular sweep of the beds across the direction of its axis in the same way that it ends to the north.†

From the Lye to Netherton church the anticlinal runs very steadily to the N.N.E., the Thick coal dipping on either hand at an angle of about 20° to 25°, and its outcrop quite easily traceable by the old workings. Just north of Netherton church the anticlinal dies away, the two outcrops meet, and the Thick coal dips north till it flattens and rises again towards Dudley.

In the centre of this anticlinal, in the canal tunnel and cutting near Yew Tree Hill, is exposed a remarkable mass of basalt or greenstone

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* I was informed that in one shaft the Thick coal was actually bent over near the outcrop, so that the same vertical pit passed twice through the Thick coal.

† Owing to imperfect and apparently erroneous information, a different direction was given in the first edition of the map to the outcrops of the coals at the south end of the Netherton anticlinal, and they were supposed to separate and spread till cut off by a fault. I owe the correction of this mistake to Mr. T. King Harrison of Stourbridge, and his ground bailiff, Mr. John Hatton. The same gentlemen also pointed out to me that the Thick coal of the little basin of the Grange (farther west), although it cropped up towards and into the boundary fault, never actually cropped at the surface, as I had been led to suppose when formerly surveying the ground.

which sends out veins into the adjacent Coal-measure sandstone, and is therefore intrusive. It is not at all necessary, however, to look upon the intrusion of this mass of trap as contemporaneous with the formation of the anticlinal elevation.

The Cradley Basin.—It appears from former and recent information that a fault runs parallel to the Netherton anticlinal on the eastern side of it, from Careless Green to the neighbourhood of Musham. I believe this fault, however, to be merely a fracture, with but a slight displacement, in the Thick coal and other measures where their "lie" changes suddenly from a nearly horizontal to a highly inclined position.

From this line of disturbance they appear to stretch across very uniformly and nearly horizontally under Cradley Heath, Congreaves, and High Haden, as also under Dudley Wood and Old Hill, till they reach the Russell's Hall fault before described, when they are suddenly bent up at a sharp angle as well as broken and heaved to a height of 300 or 400 feet.

A few small faults are met with about Baremoor and Congreaves, as shown on the map, and another small east and west fault runs through the Hawn Colliery with a downthrow of 30 feet to the south.

As the beds dip to the south, while the ground rises rather rapidly in that direction, it follows that the uppermost beds of the Coal-measures must soon make their appearance. We accordingly find the Halesowen sandstone group stretching across the coal-field from east to west, and above those we soon meet with the red beds of the Permian formation.

On the road from Halesowen to Hagley two considerable patches of Permian rock are seen to rest on the upper sandstones of the Coal-measures; one at Quarry Hill and Hasbury, and the other at Hayley Green. These Permian beds dip to the southward; but in the brook immediately south of them good Coal-measure beds can be seen, and farther south in Uffmoor Wood one, if not two, little coals have been found, and may be seen cropping into the brooks. It is clear, therefore, that these two Permian outliers are cut off to the southward by a fault which is an upcast to the south, and runs about east-north-east and west-south-west along their southern boundary.

The southern boundary of the coal-field stretching from Wychbury Hill on the west, to Lappal tunnel on the east, is formed by the horizontal beds of the upper Coal-measure sandstones and shales becoming covered as we ascend the rising ground to the south, by the horizontal beds of the Permian rocks.* It will be seen accordingly, by inspection of the map, that this boundary, instead of being smooth and regular, like that of the east and west sides of the coal-field, is indented and undulating, depending chiefly on the shape of the ground. Wherever a valley sufficiently deep penetrates to the south, there is a bay of Coal-measures marked in the map. Wherever a ridge sufficiently high stretches to the north, a promontory of red rock will be seen advancing in that direction. We have here, therefore, a true natural surface boundary of the coal-field, caused simply by the irregular denudation of the rock that covers it.

Pensnett Basin.—The Pensnett Basin is bounded by the Netherton anticlinal on the south-east, the south-western slopes of the Dudley and Sedgley ridge, and the northern part of the Russell's Hall fault on the north-east and the Western Boundary fault on the north-western and south-western. Instead of declining gently to the north and passing

* By horizontal is here meant "apparent horizontality" only. There may be a slight dip to the southward of 2° or 3°, every geologist knowing that it is impossible to detect such a slight variation from horizontality with anything approaching to certainty or accuracy, except under very favourable circumstances.

under the Permian, as in the Cradley basin, the beds of the Pensnett basin rise and crop out to the south, not only along the flanks of the Netherton anticlinal, but over great part of the ground between it and the Boundary fault.

Immediately west of the Lye, indeed, there is a little basin of Thick coal which under the Grange is at a depth of 140 yards, and seems to dip thence rapidly southwards towards Prescott, as was before described, when speaking of the south end of the Netherton anticlinal. It not only dips south, however, but rises rapidly towards the west at an angle of 45°, and cropping against the boundary fault for some distance it reaches the surface just south of the Stourbridge road, whence this outcrop strikes north-easterly, and runs parallel to the Netherton anticlinal for some distance, thus making the little trough of Hay Green and Tintam Abbey.

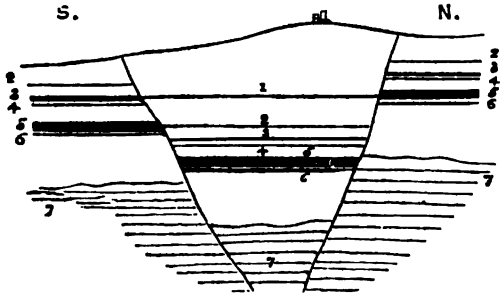
The Thick and other coals, however, are so much deteriorated here by "rubbish" that the clays become the more valuable mines, especially the Fire-clays used for making the well-known Stourbridge fire-bricks.

After striking north-easterly up to Mousehall farm the crop of the Thick coal then curves to the west towards Amblecote, and runs in a curved line to the boundary fault a little south of Brettell Lane, as shown in the map. All along this line the dip is to the north under Brierley Hill.

A few little east and west faults traverse the Amblecote and Hay Green district, and are said to extend even across the anticlinal.

Fig. 22.

Brierley Hill Trough Faults.



Scale 6 in. to 1 mile, vertical and horizontal.

1. Upper Sulphur coal.
2. Two-foot coal.
3. Broach „
4. Herring „
5. Thick coal.
6. Heathen coal.
7. Silurian shale.

Brierley Hill Trough Faults.—At Brierley Hill two much more powerful dislocations form a trough, each having a downthrow of 80 or 90 yards (or about 250 feet), in the centre of their range, but decreasing that amount towards their extremities to less than 30 yards (or 90 feet). The southern of these two faults ends on the west flank of the Netherton anticlinal, but the northern one is said to run right across it, carrying a downthrow to the south of 10 or 12 yards, and running in a curved line to Withymere, where it dies out on coalescing with the Russell's Hall fault.

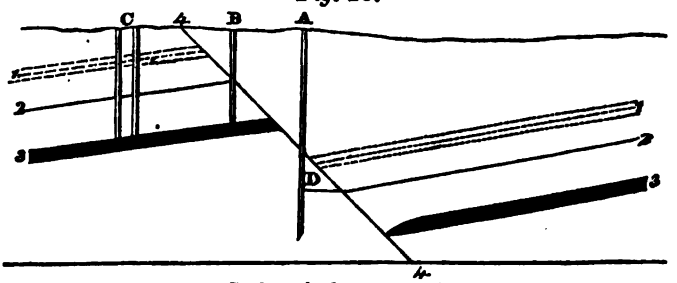
Brockmoor Fault.—On the west both these faults are cut off by the southern end of the Brockmoor fault, which, springing out of the western boundary fault north of Brettell Lane, runs about north-north-east to Pensnett reservoir, having a downthrow to the west of about

300 feet. This fault sends out two slight branches, one to the east by the Round Oak, with a downthrow to the south of 5 yards; one to the north-east through Hart's Hill, with a downthrow to the south of 10 or 8 yards. At Pensnett reservoir the Brockmoor fault is believed to branch as shown in the map.

I was informed by Mr. Pearson, of Brierley Hill, that "at Brockmoor this fault threw down to the west 130 yards, or nearly 400 feet, that it was only *a slip*, but was 200 yards wide, or made that much barren ground." The meaning of which description is, that although the fault itself had no apparent thickness, yet the two ends of the Thick coal were separated by 200 yards measured on the surface of the ground, showing the fault to have an inclination of not more than 33°.

Corbyn's Hall Fault.—The Corbyn's Hall fault strikes out of the Great Boundary fault about a mile north of Bugpool, a little west of Salter's Hall. Its downthrow is likewise to the west and north, at first 360 feet, diminishing then to 300, which it maintains for upwards of a mile. It then curves gradually round to the north-east by Shut End House, diminishing its throw to 240 feet, and thence passing through the north end of Barrow Hill by Hunt's Mill, it strikes east up to Russell's Hall iron furnaces, its downthrow being north 120 feet. I believe this is the fault mentioned by Sir R. I. Murchison in the Silurian System, p. 504. He gives a section of it on the authority of Mr. W. Mathews, in which there is an actual dyke drawn, 140 yards in width, between the broken ends of the coal. Mr. Mathews derived his information from his ground bailiff of that time, but on cross-questioning his present ground bailiff, Mr. Job Taylor, I arrived at a different and more natural explanation of the facts. I may premise, that in South Staffordshire, by the "width" of a fault is always understood *the width measured at the surface of the ground*, between the broken ends of the Thick coal, or any other bed that may be worked. It is the space of barren ground as to that particular bed, the width of which is measured in yards on the mining plan. It depends, therefore, not on the actual or real width of the fault, but solely on the angle of its inclination. This will be seen from the following account:—Job Taylor first assured me that this was not *a fault* at all, but only *a slip*, by which he meant that there was no real width or substance in the fault. He then told me that the "throw" of the fault was 90 yards, and its "width" was exactly the same, as in the following diagram (Fig. 23):—

Fig. 23.



Scale, 1 inch = 150 yards.

A, B, C. Shafts.
1. Beds containing water.
2. Brooch coal.
D. Gate-road.
3. Thick coal.
4. The fault.

A shaft (A in the diagram) was sunk, which crossed the fault between the ends of the pieces of Thick coal, and was therefore said to be sunk in the fault. But from this shaft they drove out a gate-road (D), and

on the deep side they hit the Brooch coal *in advance* of the Thick coal, as in the diagram. Moreover, there were certain wet beds (1 in diagram), beds from which water came out, above the Brooch coal. Now, in a shaft (B) sunk to the Thick coal on the crop side of the fault, these beds were not passed through, and the shaft was quite dry; while in the shafts (C) further from the fault, they were met with, and the shafts were quite wet. This likewise agrees with the diagram, and the facts are explicable only on the supposition of its correctness. Job Taylor likewise assured me that on the deep side of the fault the coal was "pinched" towards the fault by the descent of the roof, as in the diagram. If the reader will draw perpendicular lines from the ends of the Thick coal No. 3, where they are traversed by the fault, up to the surface, the space between those lines will give him the width of the fault according to the common notions of it.

*Shut End faults.**—A little north-west of the commencement of the Corbyn's Hall fault, two parallel faults strike nearly north from the Boundary fault near the Standhills, one throwing down to the west about 300 feet, another up to the west 150 feet, with a complicated and broken piece of ground between them. They coalesce or come very near together, just south of the Dudley and Kingswinford turnpike road, and thence proceed as one fault north-by-east, just west of the Shut End furnaces, with a total downthrow to the west of 180 feet. This fault, called the Shut End fault, is believed to run by Askew bridge up to the Russell's Hall fault there.

Tansy Green Trough.—It sends a considerable branch from Shut End by Cooper's bank, nearly to the Graveyards, which has a downthrow to south-east of about 120 feet. This branch forms a trough with the northern or north-eastern extension of the Corbyn's Hall fault, both running nearly east and west, and having a downthrow of about 90 feet towards each other.

Even at Shut End the fault is not a single fissure, like the Corbyn's Hall fault, but a wide dislocation made up of a number of steps or smaller fractures (see Horizontal Sections, Sheet 25, No. 7). Mr. Colly, the ground bailiff, was kind enough to give me the details of a gate-road that was driven through the fault, starting from the Thick coal on the "crop" side of it, *i.e.*, the upcast side. The gate-road was horizontal, but they met, in driving, with beds lying at various angles, of which the following are the details:—

	FT.	IN.
1. Coal and batt	9	0
2. Rock binds	42	0
3. Rock	12	0
4. Peldon	21	0
5. Rock binds	33	0
6. Pin measures	12	0
7. Herring coal	6	0
8. Bind measures	9	0
9. Brooch coal	34	6
Carried forward	178	6

	FT.	IN.
Brought forward	178	6
10. Rock binds	8	0
11. Herring coal	9	0
12. Bind measures	9	0
13. Brooch coal	9	0
14. Fire-clay	9	0
15. Two-foot coal	6	0
16. Red ground	33	0
	261	0

This red ground No. 16 was outside of the faulty ground, and at the end of the 33 feet they sank a "jackey pit," and found the Two-foot coal which they had just previously passed through lying horizontally 22 feet below them. The whole length of the gate-road was 261 feet,

* Mr. B. Gibbons, of Shut End House, described this piece of ground to me from his mining plans.

during which they twice passed along the same set of beds, rendering it probable that there was an upcast between the downcast faults. Had the dip of the several fragments of beds been given, we might have constructed a very instructive section of this gate-road.

Gornal Wood faults.—Between Gornal wood and the Graveyards there are four faults which strike south-south-west out of the Russell's Hall fault, each having a downthrow of 21 feet to the east-south-east.

It will be seen that not only these, but the other principal faults, namely, the Shut End, Corbyn's Hall, and Brockmoor faults, have likewise a general bearing of north-north-east and south-south-west where their throw is greatest and most decided, and that where they deviate widely from that bearing is where they send out branches that eventually become east and west faults, or where perhaps such faults merge into them.

These east and west faults have generally a less amount of dislocation than the others, the only large throws being in the pair of faults that make the Brierley Hill Trough, and these are only important with respect to the piece of ground which lies between them.

The general effect of the three great north-north-east and south-south-west faults, the Brockmoor, the Corbyn's Hall and the Shut End, is to throw down the measures towards the west, and extend the coal-field in that direction. If it had not been for these breaks it seems likely that the outcrop of the Thick coal south of Brettell-lane might have run in a straight line north-north-east for that north of Turner's Hill by Cotwell End and Sedgley Hall farm.

If the coal had not cropped out along that line, it is at all events very probable that the western boundary fault would have run along it with one great heave of a downthrow to the west bringing in the Permian or New red sandstone beds against the Coal-measures.

Instead of one great heave, we may look upon these three faults as subdivisions of the boundary fault, letting down the coal measures by a succession of steps towards the west before burying them under the other formations.

Between Netherton and Dudley the two basins of Pensnett and Cradley coalesce, the coals and the principal dislocation,—the Russell's Hall fault,—ranging uninterruptedly from one to the other, and the beds dipping north from the end of the anticlinal till they rise to the Russell's Hall fault.

THE CENTRAL AND NORTHERN PART OF THE COAL-FIELD.

We now come to the part of the coal-field which lies east and north of the main line of division. Before describing the position of the Coal-measures, however, it will be as well to give an account of the Walsall Silurian district and show the connexion between the beds there and those which have been already described as appearing on the Dudley and Sedgley anticlinal.

The Walsall Silurian district is of very irregular shape, owing partly to the action of several faults, partly to the overlapping of the Coal-measures. In the cutting of the South Staffordshire railway on the west of the town may be seen the calcareous beds of the upper or Little limestone. They dip west at an angle of 5°, and in that direction the Silurian shale becomes shortly covered by the lower Coal-measures containing the Blue flats and other ironstones. On the north of the town, and east of the Lichfield road, are some large old quarries, in which the lower or Thick limestone was formerly worked, dipping westerly at 10°. This limestone must be continued under the town to the southward, being concealed from view by a very thick capping of

quartzose gravel of the Drift period. Just south of the town it must be cut off by the fault which runs east and west from the south side of "the Moat." This fault is known in the Coal-measures to have a downthrow to the south of 120 feet. Its extension to the east is partly hypothetical, as from Walsall race-course no rock is seen at the surface either southward or eastward for at least a mile and a half.

In tracing the Thick limestone to the north it is seen to bend round and to be cut off by a small fault, a downthrow to the north, near "the Butts." Partly by reason of this downthrow, partly from the rise of the ground, the lower Coal-measures with the Blue flats ironstone here overlap the limestone, and run some distance to the east of its outcrop, till the gradual fall of the ground allows the Silurian shale to come to the surface again.

Near Rushall Castle is another little fault throwing down to the north, but here the Thick limestone again crops to the surface, in consequence of the denudation of the Coal-measures, and has been worked in quarries towards the north-east as far as Linley. In some of the quarries between Rushall Castle and the Halfway House the Coal-measures may be seen on the west side of the excavations resting on the Silurian shale; but the Coal-measure boundary shortly strikes north, while the Silurians strike north-west, in consequence of which at Daw End the Upper or Little limestone comes out from under the Coal-measures, and may be traced by a line of old quarries running in a curved line down towards Ketton's garden. In the canal near here a small supplementary band of limestone is found between the two limestones, and towards the Halfway House a short band of limestone was worked below the Thick limestone. These masses are called "Self lumps;" they are large lenticular masses, in which the calcareous so far prevails over the argillaceous matter as to form good workable limestone.* North and east of Daw End the Silurian rocks are altogether cut off by a great fault, which we may call the Daw End and Linley fault, running north-west and south-east, throwing down to the north-east and bringing in the Coal-measures in that direction.

In this Coal-measure tract was sunk the Trial pit at Aldridge (see Vertical Sections, Sheet 16, No. 4), and another pit between Aldridge Lodge and Hill End. This latter pit, I was informed by Mr. Roberts of the Butts, was 62 yards deep, and that three measures of coal and two of ironstone were passed through, the whole dipping east-south-east at an angle of 25°.

Starting from the Walsall and Daw End limestones, and traversing the ground to the east, we find here and there small openings or cuttings in the shale below them, but we do not get much information till we come to the banks of the new canal running from Longwood Wharf south-south-west by Ginity Graves and the Bell to the Tame Valley canal that runs by Bustleholme Mill and Ray Hall. All down this canal are cuttings in Silurian shale or "bavin," for the most part as nearly horizontal as possible.† East of it, about Hay Head, we get another limestone rising from underneath this shale at an angle of about 10°, running from the fault near Aldridge Lodge down to Daffodilly, where it begins to curve and dip at a high angle, finally ending against the "red rock" near the Skip, its last piece dipping south-west at 35°. East of this, which is locally known as the Barr limestone,

* It must be borne in mind that all the Silurian shale near these limestones is more or less calcareous, and full of calcareous lumps and nodules.

† In cutting this canal a number of fine fossils were discovered, especially heads of Eucalyptocrinus and Echinoencrinus, also many fine and rare brachiopods.

nothing is seen till we come to the "red rock;" but as near Hay Head there is a space of one third of a mile between the two, we ought, if this Barr limestone be truly the representative of the Woolhope limestone, to get the upper part of the Caradoc sandstone series in the intermediate space. The ground is absolutely flat, and rather wet and marshy, and apparently covered by drift clay, so that in the absence of deep excavations this point cannot be settled.

The above passage is left as it stood in the first edition, and it has been already pointed out, p. 109, that subsequent research proved the existence of this sandstone where it was thus anticipated, and showed that it was concealed not only by Drift clay, but by a thin covering of Coal-measures, except in one little ditch or gully at the back of the house called Daffodilly and in a small quarry near Shustoke Lodge. The sandstone, now called Llandovery, rises gently out from under the Wenlock shale, the relations of the beds being precisely the same as at the Colmers and the Long Wood near the north end of the Lower Lickey.

It is possible that the fault before mentioned, which strikes east and west from the Moat, and is supposed to cut off the limestones south of Walsall, is continued to the east, and likewise cuts off the south end of the Barr limestone.

No limestone is known, either by natural outcrop or by sinkings, south of this line. The Silurian shale, however, is seen at intervals, not only in the canal before mentioned but at other points, and was formerly exposed in the cutting of the London and North-western Railway south of Tame bridge. In a horsepond at the Goodwin farmhouse considerable nodules of limestone were got out in the year 1849, rendering probable the near neighbourhood of one of the bands of limestone to this spot. On Delves Green are many old pits in the lower Coal-measures, from which the Blue-flats ironstone had formerly been got, and one of these had been sunk as a trial pit to the depth of 50 yards, chiefly, as appeared from the "spoil" on the pit bank, in Silurian shale. Near the seventh milestone on the Walsall and Birmingham road an outlier of Coal-measures, with sandstone and ironstone, was cut through on the top of the high ground there, making it probable that the whole of this piece of Silurian shale south of the outcrop of the limestones would have been covered by a mask of Coal-measures, had the ground been a little higher and the rocks not worn down by denudation to their present level.

That the Silurian shale continues under the coal-field to the westward of the district now described, dipping gently and equably towards the west, is shown by the following facts:—

On the west side of Friar Park wood a shaft was sunk in 1849, in the first 60 feet of which one or two small coals were found, under which were some ironstones, and below them Silurian shale, in which the sinking was continued to a depth of 150 feet from the surface.*

At Hobbs Hole, a little east of Darlaston, according to the section given at p. 108, from Mr. Smallman's information, there are 292 ft. 6 in. of Coal-measures beneath the Heathen coal, then 60 feet of Limestone shale, followed by the Thin limestone of Walsall, which is there 16½ feet

* This was being done for Lord Dartmouth. I did not see the person who advised the sinking, but the man in charge on the bank was not aware that it was the "limestone shale" or "bavin" they were bringing up, although it was crowded with fossils, and had even nodules of limestone in it; and he told me *they were trying then for coal underneath it.*

thick; and at a depth of 90 feet below that the Thick limestome, which is there 30 feet thick.

At Bentley, south of Pouk Hill, the top of the Silurian shale was about 160 feet deep, and the Thin limestone 373. In the Chillington colliery near Wolverhampton they reached Silurian shale at a depth of 580 feet, and passed through shale and thin bands of limestone for more than 200 feet additional.

In addition to the above places where the Silurian rocks have been reached through the Coal-measures, we have at Deepfields the top of the Silurian shale 680 feet, and the top of the limestone 850 feet deep; at Dudley Port Silurian shale at a depth of 550 feet, the limestone at 620 feet; at the pits at Langley Green, south of Oldbury, a considerable thickness of Silurian shale passed through in a pit not more than 390 feet deep; and the same rock but a little way below the Thick coal at West Bromwich Heath pits.

If we look at these facts, together with that of the protrusion of Silurian rocks at Turner's Hill, the Hayes near the Lye Waste, and the Lickey, we are led irresistibly to the conclusion that a great floor of Silurian rocks stretches immediately under the comparatively thin covering of Coal-measures throughout all the coal-field south of Bloxwich at all events.

The central portion of the coal-field.—The central portion of the coal-field lies in the hollow or basin between the Silurian ridge of the Dudley and Sedgley anticlinal and the Walsall elevation.

If we take Tipton old church, the Moat colliery, and Princes End and that neighbourhood as a centre, the beds, being there deepest, rise thence gently towards the surface in every direction except towards the south. As they approach closely to the Dudley and Sedgley anticlinal they are bent up much more rapidly than elsewhere, the angle of inclination near that outcrop being in some places nearly vertical, and generally as much as 20° or 30°.

The beds rise more gently on the east towards the Walsall Silurian ground, at a mean angle of about 5° perhaps, but still more gently on the north, where the space between the outcrop of the Thick coal and that of the New mine coal is not less than two miles, although the vertical thickness between the two beds does not exceed fifty-six yards (or 170 feet). This gives a mean inclination of only about 1 in 62, or less than 1°. In the same way the Thick coal, when it does take the ground, between Wolverhampton and Bilston, declines so gently into it as never to be more than forty yards deep, and consequently never to be deep enough to take in the Brooch* above it for more than a mile to the southward, till it meets the Lanesfield fault. South of that district the measures in all the middle part of the central portion scarcely vary from a horizontal position. Notwithstanding the nearly horizontal "lie" of the beds over the greater part of the central and south-eastern district, the depth of any measure, as the Thick coal for instance, varies frequently. This variation is produced to a slight extent by the undulations of the surface, but chiefly by the upthrow or downthrow of the faults.

In describing the south-western district it was shown that the two basins into which it is divided were connected at the northern end of the Netherton anticlinal by a trough, which we proposed to call, from

* It is probable that over this space, even if the Thick coal did exceed that depth, that the Brooch would not come in, as the Flying reed coal or upper part of the Thick would come between them.

the name of some old ironworks therein, the Buffery trough. It is just here also, where the two anticlinals of Netherton and Dudley terminate, that there is the closest connexion between the south-west and the central portion of the coal-field. The Thick coal and other beds dip towards the Buffery trough, not only from Netherton, but also all along the south side of Dudley, whence it gradually curves round so as to dip first towards the Rowley Hills and then towards Tipton. The only thing, in fact, which separates the two districts here is the Russell's Hall fault, which is here a simple fracture and downthrow of about 150 feet towards the Buffery. If it were not for this dislocation the central and south-western districts would here become confluent, just as the Cradley and Pensnett basins become confluent.

Now it is from this neighbourhood that the most powerful and dominant fracture strikes into the central district, nearly parallel and almost in a line with the axis of the Netherton anticlinal. This fracture consists of the pair of faults which produce the Dudley Port trough.

At the time when the coal-field was first surveyed these faults were supposed to cease altogether on approaching the basalt of Cawney Hill. In the partial revision of the district, however, which I was able to make in October 1858, there appeared good reason for believing that they did not entirely cease, but that the basalt of Cawney Hill was cut off on the north by the continuation of the north-western fault, and that it was partly separated from that of Tansy Hill by the opposite fault. It is probable, then, that the Dudley Port Trough faults do not entirely cease till they strike the Russell's Hall fault a little to the north-west of Gad's Green reservoir.

Now, it is very remarkable that a small fault proceeds from the northern apex of the Netherton anticlinal obliquely towards the same part of the Russell's Hall fault. There seems, then, to be almost a direct connexion between the Netherton anticlinal and the Dudley Port trough.

If we produce the axis of the Netherton anticlinal it will strike exactly into the centre of the Castle Hill dome-shaped elevation.

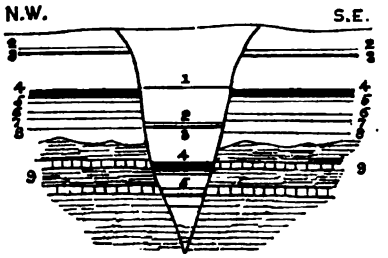
I believe we have in these and similar facts a proof that the forces of elevation and disturbance which were acting on the country to produce the principal features in the lie of the rocks acted along lines running north-north-east and north-north-west, here one force and there another predominating, and producing N.N.E. or N.N.W. fractures or elevations accordingly, with occasional oblique connexions between two parallel and adjacent lines of effect. The two forces seem also to have been sometimes so equally balanced as to have their direction resolved into lines equidistant between them, and therefore running either north or south, as in the Castle Hill and the Wren's Nest, or east and west, as in some of the large faults and dislocations. The north and south lines of course bisected their smaller angle of intersection, the east and west lines the larger angle.

Having dwelt long enough, perhaps, on what is believed to be the law governing the direction of these lines of disturbance, I will now proceed to describe those of the central district a little more in detail.

The Dudley Port Trough faults.—These are two parallel faults starting from near the Free bodies at the north-west corner of the Rowley Hills, and running about north-north-east for about 2 miles up to the Horsley collieries. They are scarcely a quarter of a mile asunder, and each throws down the piece of ground between them to the maximum depth of 130 yards; that is, the piece of Thick coal between them is 130 yards (or 390 feet) deeper than that on either side. (See Fig. 24.)

Fig. 24.

Dudley Port Trough Faults.



Scale 6 in. to 1 mile vertical and horizontal.

1. Upper Sulphur coal.
2. Two-foot coal.
3. Brooch „
4. Thick „
5. Heathen „
6. New mine coal.
7. Fire-clay „
8. Bottom „
9. Silurian shale, with Dudley limestones.

From the maximum of 130 yards, however, the throw of these faults diminishes in each direction to one of much less amount. It has been proved by the workings that each of these faults hades, or slopes downwards, towards the other at an angle of about 70°, they must, therefore, meet at no great distance below the included piece of coal, and as their throw is equal and opposite, they must, where they meet, exactly counterbalance and neutralize each other, and if continued at all, must descend as a mere fissure or crack, without producing any dislocation. It so happens that the included piece of coal is, at Dudley Port, exactly on a level with the Dudley limestone outside the faults, and the workings have been continued from the coal *into* the limestone. This likewise shows that as regards the mass of the country on each side, these Dudley Port Trough faults (or fault) are no dislocation at all, but only so as regards the piece of ground between them. Nevertheless, it is probable that they mark the line of most intense strain at the period when the elevatory forces were acting on the district. This is a point which for convenience sake we will discuss more fully farther on.

That they had the effect of materially modifying the action of the disturbing force is shown by the fact that to the southward of the Dudley Port Trough all the faults are downthrows to the north, while to the northward of it all the faults are downthrows to the south; in other words, all the faults of the central district form a succession of steps down to the Dudley Port Trough faults.

Faults between Dudley Port Trough and Round's Green.—Starting from Round's Green, between Timmin's Hill and Oldbury, we have 4 faults, with some branches, running about north-east and south-west, and throwing down to the north-west from 90 to nearly 180 feet. The course of these faults is concealed towards the south-west by the trap of the Rowley Hills, while towards the north-east they appear to die out, or at all events have not been traced. The southern fault of the Dudley Port Trough itself dies out towards the north-east, its throw diminishing to 210 feet near Horsley, where it has a small branch throwing down *to the south* 90 feet. Two small faults, with a southern downthrow, likewise start out of it near Roseland farm.

The northern fault of the Dudley Port Trough runs into and coalesces with the Tipton fault near Horsley.

North of the Dudley Port Trough we have 7 principal faults all running nearly east and west, and all having a downthrow to the south. These are (see Horizontal Sections, Sheet 23, No. 1)—

1. *The Tipton and Hilltop fault.*—This has a branch running from Tipton to the south-west, and throwing down 54 feet to the north-west; but its main line at Tipton Green throws down 45 feet to the south, and thence it runs about east-by-north to Hilltop, having a maximum throw of 150 feet to the south near the Eagle furnace, whence it diminishes in amount towards West Bromwich old church to 20 feet and less.

2. *The Bald's Hill fault,* which, just north of Mr. Davis's Crook Hay furnaces near Hateley Heath, has a downthrow to the south of 420 feet. This fault runs east as far as Stone Cross, beyond which its course has never been proved.* To the west of Bald's Hill this fault splits into two branches, the southern of which runs through Gold's Green with a downthrow to the south of 96 feet; the other runs through Hocker Hill, its downthrow diminishing from 120 to 90, and finally to 25 feet, as it runs west.

3. *The Coseley and Wednesbury fault,* which in its central part has a downthrow to the south varying from 150 to 210 feet. To the westward it splits into two, each having a downthrow of 45 and 66 feet respectively, and then diminishing to nothing. On the south side of the town of Wednesbury its throw is 90 or 105 feet, whence it runs towards Crank Hall, and probably dies out.

4. *The Lanesfield fault,* which has a downthrow to the south of 180 or 210 feet, near Hallfield, diminishing in each direction, and finally dying out. Towards the west this fault splits into two well marked branches, which have a throw at first of 105 and 66 feet respectively, the southern branch diminishing very regularly from 105 to 30 and 20 feet, the northern being cut off by one of those faults mentioned before as being very numerous and complicated in the corner of the coal-field north of the Sedgley ridge, and marking the prolongation of the disturbing power which produced the anticlinal.

5. *The King's Hill fault* is a very slight one, having a throw of not more than 20 to 25 feet to the south.

6. *The Darlaston fault* has just east of Darlaston a downthrow to the south of 66 feet. It is not known east of that, but it may possibly run along the north side of Delve's Green, where the Coal-measures stretch eastwards over the Silurian shale. To the west it splits half a mile from Darlaston, its branches diminishing to 27 and 9 feet respectively, and shortly disappearing.

7. *The Moat fault* mentioned before as running south of Walsall. It has a downthrow to the south of 120 feet just south of the Moat, but nothing more is known respecting it.

Mr. George, of Bentley, has lately pointed out to me another fault a little south of the Moat fault, running parallel to it, and likewise having a downthrow to the south.

Several other small faults may also be seen marked on the map, not worth a more detailed description.

Outcrop of the Thick coal.—It will be worth while briefly to follow the outcrop of the Thick coal over the district thus broken by faults.

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* The country here is very much covered by drift. Mr. Yardley, of Tipton Moat, informed me that at Mr. Bagnall's Moorland colliery, near Hateley Heath, it was at one pit 165 feet to the top of the Thick coal, over which there were only 51 feet of "rock binds," &c. for a roof; all the rest, or 114 feet, being drift sand and gravel.

Its outcrop along the eastern flank of the Sedgley and Dudley anticlinal ridge has already been described (p. 149), and it has been shown how it is dislocated by the western branches of the Lanesfield fault, and that a detached piece was thrown in towards the Wolverhampton furnaces in consequence of other faults having a downthrow in that direction aided by a rude sort of anticlinal arch that occurs about Parkfield.

The outcrop then runs along the western side of Ettingshall Lane for some distance, and then turns across it and across the Wolverhampton and Bilston round toward Batchcroft and Priestfield. A small east-and-west fault, with a downthrow to the north, throws in another little detached piece towards Monmore Green. The outcrop runs thence very steadily about east by south to Darlaston, where it is broken by the Darlaston fault and partly deflected to the north by the rise of ground. Thence the outcrop runs south-east till it is broken and thrown forward to the east by the King's Hill fault, whence it runs south to the Lanesfield fault, which again throws it forward to the east. Thence it begins to run nearly south-west into the northern part of Wednesbury, when it is cut through and thrown nearly half a mile to the east by the Coseley and Wednesbury fault. South of that fault it runs about south-south-west, and is deflected by the valley of the Wednesbury brook, south of which it meets the Bald's Hill fault. The outcrop is then thrown to the east more than a mile to Stone Cross, partly by the downthrow of the Bald's Hill fault, partly by the rise of ground, and partly perhaps by a flattening of the dip of the measures. From Stone Cross it strikes about south-south-west till cut by the extremity of the Tipton fault north-west of West Bromwich old church. This fault, however, is here very slight, so that the outcrop seems scarcely affected, but continues as far as the Hall End colliery. In this it meets with a fault running about north-east by north, which has a downthrow to the south-east. This would throw the outcrop still farther to the eastward, in which direction, however, everything is so covered by drift that its outcrop is not known. There then appears to be another fault ranging about north-east by east, having likewise a southerly downthrow, bringing in the red rock of the Permian formation, under which the Thick coal continues for some distance at a depth of 600 or 700 feet till it ends, either in a rock fault, an outcrop of the beds into the Permian rock, or against an upthrow fault. It is not improbable that the Thick coal terminates for a time, if not altogether, towards the east under the Permian rocks, in one or all three, of the methods alluded to above. From the south side of the Tipton fault, about two-thirds of a mile west of West Bromwich old church, a fault strikes off to the southward with a downthrow to the east, and runs thence through Oldbury to the Quinton. This will be described presently under the head of the Boundary faults.

The south-eastern part of the coal-field.—Between it and the Rowley Hills is the south-eastern portion of the district, in which the beds appear to lie very regularly and horizontally, although the Thick and other coals are greatly injured by the quantity of sandstone interstratified with them, as before described. Such as they are, however, these beds appear to have been very little disturbed by fractures and dislocations, the debased representative of the Thick coal passing under the Rowley basalt on the one side and striking against the Boundary fault on the other at a depth of 400 or 500 feet, often thinning from 30 feet to 3 feet in all directions, and being frequently not worth the trouble of getting. South of Causeway Green and Cakemoor little or nothing

is known either of the constitution or the "lie" of the Coal-measures, but they are believed to dip gently to the southward until they pass beneath the red rock found above the Lappal tunnel. These red rocks may be seen occasionally thereabouts to dip south at an angle of 5° to the south.

From the neighbourhood of the Lappal tunnel, however, it will be seen, by reference to the map, that a curious little narrow strip of Coal-measures runs out two miles to the east, as far as the Stone House near Harborne. The existence of Coal-measures at the surface along this strip is shown partly by the rubbish got out of the shafts of the tunnel near Wilderness Farm, but principally by a pit sunk by Mr. Flavel, between the Stone House and Bog Meadow Coppice. From this pit, which was 80 yards deep, nothing but Coal-measure shales and "binds," with small ironstone nodules, was extracted. The measures dipped north at about 10°, and they may possibly have dipped regularly under the Permian and New red sandstone rocks which stretch from Harborne to the Quinton, though it is much more likely that the boundary between them is a fault. On the south side of the ridge, at all events, the boundary must certainly be a fault, as near the Stone House brick red sandstone may be seen dipping south at 10°; flattening to 5° at the quarry beyond Weoley Castle.

The northern portion of the coal-field.—The northern portion of the coal-field is the part between the Great Bentley fault and Brereton. None of the faults we have hitherto been examining, with the exception perhaps of the Russell's Hall fault, exercise any marked influence on any large portion of the country. They merely traverse the beds for a certain small distance, and alter their levels over a certain limited space, the amount of the alteration soon diminishing to nothing. If either of these faults did not exist, there would rarely be any material change in the nature or character of the rocks of the locality.

With the Great Bentley fault, however, the case is different.

We have seen that between Wolverhampton and Walsall the Coal-measures crop gradually, but steadily, to the north, so that, first the Thick coal, then the Heathen, then the New mine, rise to the surface of the ground and end towards the north. The Fire-clay and Bottom coals are but a few yards deep about Bentley Lodge and Deepmore Coppice; and it is clear that if this gradual rise of the measures to the north had continued uninterruptedly for a comparatively short distance further, the very base of the Coal-measures would have come up to the surface of the ground, and the Silurian shales and limestones would then have cropped out beyond, spreading north perhaps for many miles. Cannock Chase would in that case have been a Silurian instead of a Coal-measure country.

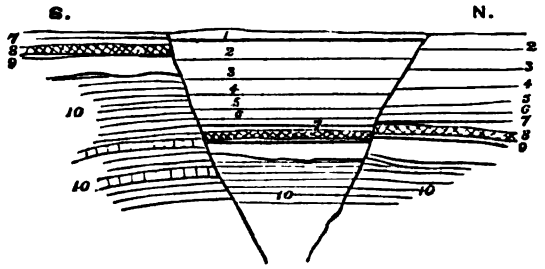
The great dislocation of the Bentley fault,* however, throwing down to the north to the amount of 120 yards (360 feet), brings in the Coal-measures even up to the base of the Thick coal, and that formation then spreads to the north, forming the surface of the ground, till it is concealed under the New red sandstone.

About a quarter of a mile north of the Great Bentley fault another runs parallel to it, throwing down to the south 25 yards, and to that extent forming a trough, or neutralizing the effect of the northern downthrow; still, however, leaving nearly 100 yards of downthrow to benefit the country on the northern side of the trough. (See Fig. 25.)

* Mr. James George, of Bentley, is my authority for all the faults of that neighbourhood, he having placed all mining plans, &c., at my disposal, and frequently communicated to me all the information he possessed.

Fig. 25.

Great Bentley Fault.



Scale 6 in. to 1 mile, vertical and horizontal.

1. Old man's coal.
2. Bentley Hey „
3. Heathen „
4. Sulphur „
5. Yard „
6. Bass „
7. Fire-clay coal.
8. Green-rock trap.
9. Bottom coal.
10. Silurian shale, with Dudley and Walsall limestones.

In the trough between these two faults, on the south side of Bentley Heath, they get a nine-foot coal, called the Old Man's coal, which crops out shortly in each direction, as it is never more than 5 or 6 yards deep. The Bentley Hey coal, 5 feet thick, is 50 feet under this; and the Heathen coal, 50 feet under the Bentley Hey. We have already seen that the Old Man's and the Bentley Hey coals must, if even only on account of their relation to the Heathen coal, be the bottom beds of the Thick coal separated into two.

The eastern outcrop of the Old Man's coal in the Bentley Trough is just north of the Bentley furnaces, the Bentley Hey coal cropping west of the canal near Birch Hills, and the Heathen and lower coals cropping out successively to the east as we follow the trough towards Ryecroft.

The Great Bentley fault appears to branch towards the east in the manner represented in the map, its branches running up to Rushall and dislocating the measures there, as before mentioned in the description of the Walsall Silurian district. To the northward of the Bentley Trough, the Bentley Hey coal crops in the bed of the brook (which afterwards forms the little river Tame), north of the Bentley Heath furnaces, and the Heathen coal crops a little to the eastward of that.

These two outcrops run off northward with an undulating line in consequence of slight undulations in the surface and variations in the dip of the beds, for about a mile, the general dip being to the west at an angle of 3° or thereabouts. Several east and west faults are then met with, the most important of which runs north of the New Invention and south of Bloxwich. This in the centre of its course has a downthrow to the north of 195 feet (65 yards) diminishing, apparently, in each direction. Two little faults, with insignificant downthrows to the south, run between this and Sneyd's Pool reservoir, while one to the south of it running through Herbert's Coppice has a downthrow to the south of 45 feet (15 yards) with another very small one to the south of it, having a small downthrow to the north. After being dislocated backwards and forwards by these faults the Bentley Hey coal crops at the south side of Sneyd's Pool, beyond which nothing is known of the outcrop, although the coal itself is met with in the deep sinkings

at Essington and Wyrley *below* the coals worked there, as also in the deeper pits of the Brown Hills district, *above* all the coals that are usually gotten in that neighbourhood.

The Heathen coal crop is known, after traversing the New Invention fault, in the south-western part of Bloxwich, beyond which it has not been traced, though the coal itself is also said to occur in the deep pits of the Brown Hills district at the proper distance below the Bentley Hey coal.

The outcrops of these coals ought eventually to be discovered along the line of country running by Little Bloxwich, Fishley, and Little Wyrley, or Wyrley Common.

Let us return now to the Bentley and Birch Hills district. It appears that the northern fault of the Bentley Trough likewise splits up towards the east, the branches running off to the east-north-east, and dislocating the lower Coal-measures and their outcrops in the way represented in the map. Mr. Beckett, of Wolverhampton, is my authority for the three faults running about north-east and south-west from Birch Hills Hall to Harden, and through Goscott Lodge and Coal Pool, which are delineated on the map. The latter appears to be the same as the northern branch of the northern Bentley Trough fault.

It will be recollected that the New mine coal is here already separated into two, known as the Yard and the Bass coal, that the Fire-clay coal changes its name, and further north is called the Cinder coal, but that the Bottom coal continues to carry a thickness of 12 feet, (whence about Goscott it is sometimes called the Thick coal,) up to the southern corner of Pelsall Heath.

This Bottom coal was admirably exposed in October 1858, in a long open work east of Goscott Lodge, belonging to Mr. Brewer. The coal here ran north till it was cut off by a fault having a downthrow of some ten yards to the north, which is believed to be the extension of one of the faults already quoted as communicated by Mr. Beckett.

From all the accounts I could collect it appears certain that the faults are even still more numerous in this district than they are represented to be in the map, their complications being in some places so great as not to be unravelled without maps on a much larger scale, and hardly perhaps even then. The lie and position, then, of the faults and of the broken outcrops of coal about Harden and Goscott, and thence up to Pelsall, which are given in the map, are to be taken as to a certain extent hypothetical. They represent the simplest and most consistent and logical explanation that could be arrived at, of a number of isolated facts, which could not be represented at all without some partly hypothetical connexion.

About Pelsall Heath I am indebted to Mr. Gilpin, of Church Bridge, and his ground bailiffs, — Russell and John Brooks, of Pelsall, for much recent information.

It was from their accounts, confirmed by that of Mr. Brewer and others, that I learnt the precise spot where the Bottom coal begins to separate into two, namely, just at the old public house known as the Red Cow, at the south end of Pelsall Heath.

I must also quote Mr. Gilpin as my authority for the fault running north-east and south-west to the northward of Pelsall Heath, with a small upthrow to the north-west, as shown by the Yard coal just coming in at the corner of Pelsall Heath on the south side of it, while none was found immediately north of it, though it existed under the hamlet marked Pelsall on the map. The Deep coal (or lower part of the Bottom coa was said to crop in Rail's coppice, and was only three

yards deep in a field immediately south of the Ryder's Hayes colliery. As, however, the Deep coal is got in the Ryder's Hayes pit at a depth of forty yards, it is clear there must be a fault with an upthrow to the south of at least twenty yards just south of the Ryder's Hayes colliery.

North of this there are several east and west faults, all having a downthrow to the north, which were pointed out to me by Mr. Gilpin, and also by John Birch, of the Brown Hills. One with a downthrow to the north of twenty yards runs just south of "The Moat," while north of that there is one with a downthrow of three yards in the same direction. Other small faults were spoken of as running parallel to these, and eventually another downthrow of twenty yards to the north, a little south of the canal bridge, now generally known as the High Bridge.

High Bridge Trough.—A little north of the High Bridge there runs, according to the same authorities, a fault about west by north and east by south, having an upthrow to the north of eighteen yards. There is thus produced a trough (which we will call the High Bridge Trough), and in this the Deep coal is worked close to the canal just south of the bridge, at a depth of 100 yards. As we cross these faults from Rail's coppice by Ryder's Hayes to the High Bridge Trough the outcrop of the coals will necessarily be thrown to the east by each downthrow, so that in the High Bridge Trough the Yard coal, and perhaps the Bass coal, will alone be able to crop to the surface before the beds are cut off by the Clayhanger and Daw End fault, which runs north and south from the Brown Hills, and will be spoken of hereafter.

North of the High Bridge Trough there are several other east and west faults, as pointed out to me by John Birch of the Brown Hills, having upcasts to the north, and therefore throwing the crops of the coals to the west, until we arrive at a curved fault running from Wyrley Hays by the canal south of Birch's coppice, which has been inserted from the mining plans put at the disposal of the Norton Manor Commissioners, of which we owe the inspection to the kindness of Mr. Beckett. North of this fault the crops of the Yard, Bass, Cinder, and Shallow coals range, apparently unbroken, through Birches coppice to the north till we reach the Rising Sun trough, the Deep coal cropping into or against the Clayhanger and Daw End fault, as formerly described to me by W. Arblaster and confirmed by John Birch. The two little east and west faults near Fishly and the Woodhouse are inserted on John Birch's authority, while those running north-east and south-west between Wyrley Common and Birch's coppice are taken from the mining plans just now alluded to.

Rising Sun Trough.—Approaching Watling Street between "The Rising Sun" and "The Machine" we meet with another twenty-yard trough, as described to me on the ground by John Birch. This will again throw the outcrop of the Yard coal very close to the Clayhanger fault, and thus place the beds in the same relative position as they have in the High Bridge trough. It is in this Rising Sun trough that the deep pit was sunk by Mr. Harrison which passed through the Sulphur, Heathen, and Bentley Hey coals, facts which enable us to connect, with much more assurance than before, the Brown Hills coals with those of Wyrley.

North of the Rising Sun Trough the faults, with their downthrows, are inserted from the authority of the mining plans used by the Norton Manor Commissioners, and the outcrops of the coals have been drawn in accordance with the indications given by those faults and the fact of the occurrence of the different coals in the different shafts, and their depths from the surface.

The lie and position of the beds hereabouts have already been partly described (pp. 72, 87), as it was necessary to do so in order to arrive at any conclusion as to their structure and constitution. It was shown that however broken and dislocated the beds might be by the different faults that traversed thom, they nevertheless preserved all the way from Bentley and the Birch Hills, by Pelsall up to Watling Street, a steady dip to the west of about 3° on an average. North of Watling Street, however, they begin to curve round so as to dip first west-north-west and then north-west, and even north-north-west, at the same low angle of inclination.

Mr. Bills, the ground bailiff of the Cannock Chase colliery, informed me, in October 1858, that they had driven gate-roads in the coals to the north-westward of their present shafts for a distance of 500 yards without meeting with any appearance of a fault or anything that would seem to interrupt their working. The pits then in use were just south of the place, where "*Little*" of "Little Longfield" is engraved on the map, so that they must have now driven under Norton Bog. He informed me that the beds dipped very slightly towards the north-north-west, being sometimes absolutely horizontal over a considerable space. He confirmed the "lie and position" of the faults drawn in the map about Norton and Norton reservoir.

I was formerly informed by a collier working at Pelsall that on following the Shallow coal from Pelsall wood towards Fishley it was found to get gradually thinner, and eventually to die out altogether. I was also informed by Jesse Potts, of Wyrley, and others in that neighbourhood, that the Wyrley Eight-foot or Bottom coal cropped a little east of the Bloxwich road about Jacob's Hall.

All the measures of the Wyrley district have a gentle westerly dip, so that the highest beds are only to be found in the most westerly shafts, while they crop out successively towards the east. The most westerly shaft is that of the Waterloo colliery, near Longhouse, where they got, at a depth of 150 feet and a height of 76 feet above the Old Robins coal, a group of beds having 7 feet 4 inches of coal separated by partings of two or three feet, with another little coal 10 feet above them. The beds soon crop out to the east, and are not known in any other of the Wyrley pits. At Essington colliery, however, they get a similar group of beds at a height of 61½ feet above the Old Robins coal, having a total thickness of 7 feet 4 inches of coal with one little parting of 2 inches, and another small coal above them. These two groups of beds are evidently the same, and they are probably the coal which has been found in the wells and in the foundations of the houses at Wyrley bank, just striking the high ground there.

Mr. Gilpin has lately informed me that the whole of the Wyrley district is chopped up by faults of greater or less magnitude, and so numerous that he found it quite impossible to trace them on the one-inch map. The three north-north-east faults, formerly marked on the map, are correct so far as they go, one running through Great Wyrley with a downthrow to the west, and two others running a little east of Wyrley bank with downthrows to the east of twelve and sixteen yards respectively. Of these two the most eastern splits up, towards the south, into several branches, and terminates. The other one, however, continues with an increasing throw towards the south, and turns off towards the east-south-east with a downthrow northwards of thirty-two yards. It may possibly run off in that direction till it is connected with the northern downthrows on the south side of the High Bridge Trough. A little south of Wyrley bank this fault is crossed by another running nearly east and west, with a downthrow to the south of twenty

yards. Mr. Gilpin also informed me that among the numerous faults about Church bridge there was always found six or eight yards of red clay *in the fault;* the fault having that width, and being filled with red clay.

In consequence of these numerous faults it is impossible to lay down upon the maps the outcrops of the coals in any intelligible manner. The dotted lines drawn on the map represent the general approximate boundary of the area within which the respective coals may be found, rather than their actual outcrop. Even where they are not broken by actual faults they appear as they approach the surface to flatten and undulate, which undulation of the beds, combined with that of the surface, causes each bed to crop in and out several times successively before its final disappearance.

Added to all these difficulties is that caused by the occurrence of vast quantities of drift, as much as 60 feet of running sand having been sometimes found, as well as clay and boulders. The boulders are many of them granite and often of very large size.

The most southerly of the shafts that can be said to belong to the Wyrley district are two near the Warstone. One of these, situated just about where the "o" of "Warstone" is engraved on the map, has the Wyrley Bottom or Eight-foot coal at a depth of 180 feet (60 yards), while in another pit, about 200 yards to the eastward of it, that coal is only 105 feet (35 yards) deep. The Cannel coal accordingly must crop between these two shafts. At the coal-pits now at work immediately to the east of the Old Mitre, the Cannel coal was only 10 yards deep. It must, therefore, crop a very little way to the eastward of these shafts.

At Mr. Mills's new colliery to the westward of the Old Mitre (just where the "T" of "The" is engraved in the map) the Cannel coal is 396 feet (132 yards) deep, proving, with the gentle dip of the measures, that there must be a fault with a large downthrow to the west, between these two places. The amount of this downthrow is stated at 65 yards (195 feet). The dip of the beds on the downside of this fault is about west-north-west, in which direction they will pass obliquely under the red clays, &c. of Essington Wood. By means of these red clays and the New and Old coal workings on the opposite side of the lane, the fault can be traced by Holly Bank and the Warstone up to Cheslyn Hey, where it probably runs into the western boundary fault.

Its course is about north by east, and there is another little fault parallel to it, some distance east of the Old Mitre, with a downthrow to the west of 15 feet (5 yards).*

South of the Essington pits little or nothing is known either of the constitution of the Coal-measures or the "lie and position" of the beds till we reach the greenstone of Wednesfield on the one side, and the Bentley and Bloxwich works on the other.

An old shaft sunk a little east of the New Invention seems to have gone through nothing but Greenstone, of which large blocks may still be found under the soil full of veins of some zeolitic mineral. Other sinkings are reported to have been made formerly to the north of this, between Essington and Pelsall in the district called Essington Wood, and the measures were said to be all destroyed by white rock and green rock trap. White rock trap is to be seen in the cutting of the railway near Landywood, which is the farthest point north at which it is known to exist.

It is also found, as before mentioned, south of Bloxwich about Birch Hills and thence to Pouk Hill, burrowing in the lower measures, and dislocated with them by the various faults that traverse them.

* We are indebted to Mr. Beckett for much of the above information, he having gained it from Messrs. Mills, and from Mr. Smallman, the ground bailiff, of Wednesbury, as also from Mr. Chekley, of Spring Hill, near Bloxwich.

If now we go north of the district already described towards Cannock Chase, we meet, first of all, with the old outcrop of coal north of Norton church which has been already spoken of as probably either the Bentley Hey or the Wyrley Eight-foot coal. This coal strikes north-east and south-west, with a dip to the north-west.

Farther north still, is the old outcrop running from near Heathy Hays to Cooper's Lodge, the old pits at Cannock Mill, and the old and present sinkings at Hednesford. At all these places the dip is said to be towards the north-west.

In the old workings on the north-west side of Hednesford Pool a number of step-like faults were said to have been met with, throwing the beds up and down in various directions, but principally down to the west to the amount of a few yards at a time.

From Norton and Hednesford the beds appear to strike regularly north-east towards Beaudesert and Brereton.

The outcrop of a coal may be seen in the valley of the brook south of Castle Hill, while another outcrop may be seen in a little gulley on the north side of it in Beaudesert Old Park. Old coal-pits are scattered all over this old park, all of which were said to go down to the same coal, and none to have been more than about 30 yards deep.

This coal must accordingly lie as nearly as possible in a horizontal position. Beyond it the beds seem to have changed their dip to the south-east.

At the Brereton collieries the general dip of the beds is south-east, at an angle of about 3° to 5°. There are 15 coals, some of which are very thin, in a total section of about 620 feet (see Vertical Section, Sheet 16, No. 1).

On the eastern side of the workings they drove out from the Fifteenth coal, which is there about 460 feet deep, towards the eastward, and came into a hard gravel rock. This was, doubtless, one of the conglomerates of the New red sandstone,* and the fault bringing it down to this position was part of the eastern boundary fault of the coal-field. This fault runs just under Mr. Poole's office. South and south-west of this point several shafts have been sunk through some of the beds of the New red sandstone down to the coals. These New red sandstone beds consist of red and white sandstone, and gravels, with some red marls; they appear to be quite horizontal. In the lower grounds they are about 70 or 80 feet thick, but measuring from the top of the inclined plane of the Hayes colliery, belonging to the Marquis of Anglesey, they are nearly 200 feet thick. The coals rise regularly from Brereton Hayes wood, where the Coal-measures are at the surface, at an angle of 3°, so that under the New red sandstone they crop up into the base of that formation. In the pit below the foot of that inclined plane, for instance, they had—

	FT.	IN.	
1. Gravel	80	0	New red sandstone.
2. Red and yellow marl	6	0	
3. Rock	5	0	
4. Clod and batt	5	6	
5. First coal	4	6	
6. Intermediate, with Three coals	125	0	
7. Fifth coal	4	0	
	230	0	

* Mr. Vernon Poole, Lord Talbot's agent, gave me this and all other information as to the mines under his charge.

While at the top of the incline they got—

	FT.	IN.	
1. Gravel - - -	120	0	New red sandstone,
2. White sand rock - -	69	0	189 feet.
3. Clod - - -	110	6	
4. Fifth coal - - -	4	0	
	303	6	

A little beyond the top of the incline is a fault running north-east and south-west, throwing down to the north-west 25 yards.

About ¼ of a mile north-west of this another pit has been sunk, in which they got—

	FT.	IN.	
Gravel - - - -	186	0	New red sandstone,
Ditto and White sand rock -	129	0	315 feet.

when they came down into the Coal-measures, and were stopped by water; they then bored into a coal just below which was supposed to be the Fifth coal.* Farther on, nearly a mile to the north-north-west, in a field of the Birches farm belonging to Lord Lichfield, just south of the Rolling Mill Pool, a boring was made some years ago, the account of which was given me by Mr. George. In this boring they passed down through 418 feet of alternations of "red rock," "gravel," "marl partings," &c. Below that they came into "black marl," and then had alternations of "black marl," "red marl," "white rock," "ironstone," and "red rock," and marls to the total depth from the surface of 612 feet. At a depth of 545 feet they are said to have found a coal 13 inches thick, with a foot of fire-clay below it, and alternations of "red rock," "red marl," and "blue binds" below that. What these lower rocks were, whether they were true Coal-measures, or whether they were Permian rocks. which, as we have seen, do contain fire-clay and coals, it is exceedingly difficult to say. The mention of ironstone would seem to give it in favour of their being Coal-measures, but there are ferruginous concretions in some of the Permian rocks which in the auger of the boring rods might seem to have been derived from true Coal-measure ironstones.

From the Brereton district, where, as we see, the Coal-measures are partly covered by some beds of the New red sandstone formation, resting unconformably on the edges of the coals, a range of hills runs south-west, ending in the bold ridge of the Hednesford Hills. All the high ground of this range is composed of beds of soft red and white sandstone and gravel, which apparently belong to the New red sandstone formation. Along their south-east margin, old coal-pits are abundant, and wherever a little valley cuts into them, the old coal-pits run down it for a short distance. Old coal-pits, with abundance of coal shale on their banks, are found on both sides of the Hednesford Hills, and everything goes to make it probable that at this northern side of the coal-field the

* I was indebted to the late Mr. Figgins for information as to all the collieries under his care.

No farther operations seem to have been carried on at this boring on Flaxley Common, and I think it exceedingly doubtful whether they reached Coal-measures at all: Any such information derived from boring is always of the most uncertain and untrustworthy character.—(Additional note in 1858).

boundary is formed by an unconformable overlap of the New red sandstone resting horizontally, or nearly so, on the slightly inclined edges of the Coal-measures. Near Littleworth there are some clay pits, in which blue bricks are made from some beds that appear to be the upper red clays of the Coal-measures, like those at Rumour Hill, at Essington Wood, and at Walsall Wood. If this be so, and our identification of these measures be correct, it will follow that all the Essington and Wyrley Coal-measures will there be found below, and probably, therefore, all their coals and ironstones.

The reader will recollect that the southern margin of the coal-field was formed by the Permian rocks resting on the upper Coal-measures in *apparent* conformity, both being horizontal, or dipping at the same imperceptible angle to the south. Both the north and south boundaries of the coal-field, then, are formed by the simple denudation and removal of the superior rocks, and the consequent appearance of the lower ones at the surface of the ground; the only difference in the two cases being that in the one the superior rocks were in apparent conformity to the inferior, while in the other they were distinctly and obviously unconformable.

CHAPTER XII.

The Boundary Faults and the Rocks surrounding the Coal-Field.

We will now examine the east and west boundaries of the coal-field. One difference between these and the north and south boundaries will strike us at the first glance of the map. Instead of being irregularly and deeply indented, and conforming to the natural surface of the ground, advancing or receding with its hills and valleys, the east and west boundaries are regular and equable, preserving a certain mean course with great persistency, and when curving, doing so gradually, and with a wide and steady sweep, forming a curve of large radius. The north and south boundaries are like an indented coast line, the east and west are like artificial roads, going nearly straight across the country, with but little respect to the variations in its surface. These boundaries, indeed, are not the result of mere denudation alone (or of that action by which the present configuration of the surface has been produced), but of denudation combined with great longitudinal faults, which at the very period of their formation produced a sudden change in the ground along their line, so that no subsequent lowering of the level of the ground, though it may slightly shift the position, can much alter the character of that change. This difference in the nature of the two boundaries has a very important practical bearing. When the boundary of a coal-field has been formed by

simple denudation, without any faults in the neighbourhood, we can follow the beds of coal under the other rock without much regarding it; it is simply an additional matter of so much thickness interposed between the surface and the bed, and if the dip of of the two rocks be known, and the surface be levelled, the depth of the coal can be calculated with the greatest facility. When, however, the boundary of a coal-field is caused by a fault, the mere dip of the rocks is no longer a trustworthy guide to us. The "throw" of the fault, as also the angle of its inclination, or "hade," is *à priori* unknown to us; we have therefore commonly no means of judging how far the coal-bed is depressed on the other side of the fault below its level on this, and if we knew that, we should perhaps have no means of ascertaining how far the fault "haded," "overhung," or "inclined;" or, in other words, how far we ought to go beyond the broken end of coal on this side of the fault before we felt sure that we were standing over the other end of the bed on the other side of the fault.

The determination of the nature and character of the boundary faults of the coal-fields, therefore, is one of the most important practical points which it is the province and the duty of a Geological survey to solve, since it is one of those least within the power of an individual observer, examining only small and isolated localities, to understand and explain.

I was at one time strongly inclined to entertain the supposition that the boundary faults of the Midland coal-fields were of the nature of cliffs rather than of fractures. It appeared from certain circumstances rather probable that the previously existing Coal-measures had been almost entirely destroyed and washed away, except in the parts where they are now seen at the surface; that in those parts they had been left as islands, round which the beds of the Permian and New red sandstone had been deposited, abutting against the old Coal-measure cliffs, their beds taking the place of those that had been swept away. Facts such as those we have seen in the Brereton district, where the coal cropped up into the New red sandstone, without the intervention of any fault, lent strength to this hypothesis. Soon after the commencement of the survey of the South Staffordshire Coal-field, however, my belief in this hypothesis was greatly shaken, and it was finally abandoned, so far as the supposition of any long line of lofty cliff was concerned, having a more or less nearly perpendicular face, with several hundred feet of New red sandstone deposited against it. The very form of the east and west boundary faults of this coal-field was against this supposition. Direct evidence against it, as to the West Bromwich district at all events, was soon obtained, and all doubt was finally set at rest when the boundary between the New red sandstone and Permian formations was surveyed. For it then appeared that sometimes a broad tract of Permian rock lay next outside the boundary fault, sometimes none at all. If, therefore, the gap caused by the supposed denudation of the Coal-measures had been first of all filled up by Permian, it would follow that that formation itself

had subsequently suffered an almost equal amount of destruction, and another great cliff formed; and that in some places the whole of the Permian formation had been utterly removed, and the old Coal-measure cliff re-exposed, only to be again concealed and the second gap filled up by subsequently-formed beds of New red sandstone. Such a recurrence of so singular a phænomenon was too much for the wildest hypothesis to affirm; and we shall, I think, see reason to conclude that the east and west boundaries of the coal-field are not only genuine faults, clean-cut fractures, but that they were produced late in the New red sandstone period, if not subsequently to it altogether.

The practical bearing of this discussion will be at once seen, if we reflect that on the first supposition of the boundaries being cliffs, a very large part of the Coal-measures, with their accompanying wealth of coal and iron, must have been removed from the spaces between our present coal-fields; if, on the other hand, the boundaries are faults, we have still all or the greater part of the Coal-measures concealed and untouched under the New red sandstone of the great central plain of England.

We will now examine a little in detail these two boundary faults, commencing with the eastern one near its southern extremity on the Birmingham and Halesowen road.

The Eastern Boundary fault.—At Perry Hill the angular trappean breccia of the Permian rocks is seen in the cutting of the road, the Red rock extending up to the turnpike. Near the Hagge, Round Hill, and "Barn," yellow Coal-measure sandstone may be seen. Just where "ra" of "Brand Hall" is in the map is an old quarry in the calcareous conglomerate, described before as occurring in the Permian rocks. This band of calcareous conglomerate can be traced thence to Barnford Hill, where it is much farther from the fault than it was at Brand Hall. This looks as if the fault increased in amount as it ran south, concealing more and more of the Permian rocks, and thus bringing this conglomerate bed nearer and nearer to it.

About 350 yards south-west of Langley mill there is an old pit only 130 yards (390 feet) deep, which, from the quantity of Silurian shale full of fossils on the bank, must have had almost the whole of its lower half altogether in that formation.* This is very near the boundary fault, but how the Silurian shale comes to be so near to the surface as even 100 yards is not easy to explain. From some old mining plans of this locality lent to me by Mr. S. H. Blackwell there appeared to have been here a curious complication of faults, the clue to which I did not succeed in unravelling. A little north of this, in Mr. Chance's pits, the Thick coal thinned out to 7 feet as it approached the fault. Red rock can be seen at the surface very near the line of the fault as it is drawn on the map. It is probable, then, that there is here a complication similar to that described before in Lord Dartmouth's Heath pits at West Bromwich.†

* It is a curious instance of the frequent want of the commonest knowledge in this district, that an intelligent man who acted often as a "ground bailiff" in the neighbourhood, his father and brother being both of that profession, was yet not aware that it was impossible to find coal beneath shale containing Silurian fossils.

† A dotted line was drawn on the map to call attention to the probable connexion between these two places. This connexion subsequent workings near Spon Lane have proved not to exist on the Thick coal level all the way, at all events not to run along the exact line drawn in the map, though it may run a little farther east of it.

North of Oldbury the fault is very well traced. At the Flash we have the Thick coal 60 yards (180 feet) deep on one side, and 212 yards (636 feet) on the other, giving a downthrow of 152 yards (456 feet); but the amount of "red rock" sunk through was not known. At Mr. Bennett's pits at Ireland Green the Thick coal is 170 yards (510 feet) deep, while on the other side of the fault, near "the Oaks," it is 288 yards (864 feet), giving a downthrow of 118 yards (354 feet). At the Terrace pits at Christchurch the Thick coal is 252 yards (756 feet) deep, and it was said to be only 45 yards (135 feet) to the bottom of the "red rock," the downthrow of the fault being 88 yards (264 feet). This fault continues to hold its course to the northward for a mile beyond this point, having still a downthrow to the east of 60 or 80 yards (110 to 240 feet), till it appears to be cut off by the Tipton and Hilltop fault. North of the Cross Guns Inn, however, in the Wolverhampton and Birmingham road, it is no longer the boundary of the coal-field even at the surface, as there is no red rock on either side of it. At a new pit sunk about the foot of the "L" of "Lyndon" in the Ordnance map they sank below the Broach coal without meeting with any red rock. From the depth of the Broach here it will be about 200 yards (600 feet) to the Thick coal. About one-third of a mile to the south of this spot is the Lewisham pit, at which the Thick coal is 290 yards (870 feet) deep, and there is said to be 105 yards (315 feet) of red rock above the Coal-measures. It is doubtful whether there be a fault, downcast to the south, between these two points, or whether the lower level of the Thick coal at the Lewisham pits is due merely to the southerly dip of those from Lyndon. A dip of 10° would be sufficient for the purpose. If there be no fault, the Permian red rock must come in either by simple capping of the Coal-measures, or it may have been originally deposited in a sudden hollow of erosion existing formerly in the Coal-measures of that locality. East of Lyndon and north of the "red rock" the Thick coal is said to end at a depth of 200 yards (600 feet) against a mass of "rock and rig." This is probably an extension of the "rock fault" found both in the "Heath" and "Lewisham" pits as before described.

From this point we have to traverse a district of very great obscurity for two or three miles. A ridge of drift gravel runs from Sandwell park by West Bromwich old church to Charleymount. This drift is in some places 120 feet thick, and effectually screens all the rocks below from observation. At a small public house between Bird End and the Wigmoor station gas escapes from the ground in such quantity that it is used to light the house and the neighbouring cottages. It is almost certain, then, that there are Coal-measures under this spot, though they can only contain the lowest beds of coal. In the cutting of the railway to the north-east of Crank Hall farm Silurian shale full of fossils was found lying horizontally.

In the road going from Wigmoor station to Newtown, red rock may be observed apparently horizontal. "Red rock" spreads from this point over all the country to the north and east. Trusting to these facts, a dotted or supposed fault has been drawn from the Cross Guns to Sunday Bridge. From this point towards the north we have on one side of a certain line running about north-by-east, Silurian shale dipping very slightly to the south; and on the other side, red rock, which, whenever it is exposed, is found to have an easterly dip.

On the Walsall and Birmingham road, as we rise from the Silurian flat about the Bell, on to the gentle elevation on which the Gough's Arms stands, we meet first with some pale wine-coloured mottled calcareous sandstone, above which, in a brick pit, we find some grey

and mottled clays and marls, with interstratified sandstone bands, that dip apparently east-south-east at 40°. Over these in a field opposite the Gough's Arms is a band of the calcareous conglomerate, just the same as that of Barnford Hill before described, dipping east-south-east at 20°. These are all evidently Permian beds. On the higher ground, where "Quarry" and "Snail's Green" is engraved in the Ordnance map, we find a large gravel-pit opened in the quartzose conglomerates forming the base of the New red sandstone.

Further north we get red sandstone and marl, probably Permian, on a level with the Barr limestone near "the Skip," and following on to the east of Hay Head we find red rocks to the east of a certain curved line, while there are Silurian and Coal-measures on the west of it. The way in which the two little bits of Llandovery sandstone are allowed to peep out at Shustoke Lodge and behind Daffodilly, while over the intermediate space the Wenlock shale appears to come directly against the red rock, may be explained on the supposition that the fault here is a waved and gently indented line, and that as the Silurian beds crop towards the east, when the fault makes an eastward bend, it allows the lower rock to crop out, while when it bends to the west it cuts into higher beds, and of course prevents the outcrop of the lower.

So far I have endeavoured simply to describe facts, and give their most obvious explanation. Still it cannot be denied that there is something yet to be learnt respecting the nature of the boundary of the coal-field between Hay Head and Lappal. We may readily allow the boundary between the red rocks (taking Permian and New red sandstone together) on the one side, and the Silurian and Coal-measures on the other, to be an ordinary fault with a large downthrow to the east all the way from Hay Head south to Sunday Bridge. But we are then driven to the supposition that it splits, and that of the two branches into which it divides, one soon ends in the red rocks, and the other goes on at right angles to the former course* until it meets another fault running parallel to the first, and likewise forming a boundary between the red rocks and the Coal-measures. Now there is, in fact, little or no evidence for this splitting of the boundary fault, and we cannot at all satisfactorily account for the southern termination of the part of it that runs by Barr.

Again, the fault running by Oldbury is certainly a large downthrow to the east, and it certainly forms the boundary line between the red rocks and the Coal-measures at the surface, but it can hardly be called the boundary of the coal-field, inasmuch as the coals are got for a mile or more to the east of it, at only a comparatively slight increase of depth. Not only so, but the Coal-measures appear even at the surface on the eastern side of this fault, both north of the red rocks towards West Bromwich, and southwards towards Wilderness Farm and the Stone House. That this appearance of Coal-measures is due to cross faults cutting off the red rocks in each direction is at present a mere arbitrary and gratuitous supposition, though it is perhaps the most probable explanation of the facts that can at present be given.

Mr. Hull examined and determined the boundaries of the New red sandstone from Hampstead Hill through Smethwick and Harborne, and

* It might give a more natural aspect to the facts, perhaps, if we supposed another branch to spring from the boundary fault between Ray Hall and Small's farm, and run a little north of West Bromwich old church to the fault that cuts off the Thick coal crop of the Hall End colliery. This line of fault would blend with that which certainly runs under the Cross Guns more easily than the one engraved on the map south of Church Vale, or, perhaps, the two together might form steps letting down the Thick coal under Virgin's End, &c.

arrived at the conclusion that the boundary between the New red and that considered to be Permian was not a fault but a natural boundary, a conclusion in which Professor Ramsay believes him to be correct.

We are, therefore, left to mere conjecture as to the lie and position of the Coal-measures below the red rocks east of the line up to which they have been worked.

It will be more convenient now if we go to the northern end of the eastern boundary fault and trace it southwards. In the Brereton colliery they drove through the fault, and found some part of the conglomerates of the New red against the fifteenth coal at a depth of 460 feet. New red conglomerates rest upon the Coal-measures here on the western side of the field without the intervention of any fault, but it does not follow that they are the same beds of conglomerate, and it is quite possible that those found at this depth in the workings are much higher in the series than those found at the surface at Stile Cop and the neighbourhood. The downthrow of the fault, therefore, may be a great deal more than that 460 feet, and there may be a succession of step-like downthrows outside it again. One such step-like downthrow was observed in a gravel pit at no great distance from the spot. Starting from this point along the line drawn on the map to the southward, we have abundant evidence of "Red rock" on one side, and of Coal-measures on the other, lying just below the surface of the ground in a nearly horizontal position. The Red rock is the ordinary Red sandstone of the New red formation. In Beaudesert Park it is apparently one of the soft red sandstones that were formerly called Brick red sandstone; about Cannock Wood the beds are white and brown sandstones, and on Old Lodge Hill are some excavations in red marl that appear to be just the bottom beds of the upper subdivision of the formation, the Red marls. From this point scarcely anything can be seen or known for about two miles, till we arrive at the Hammerwich colliery just east of the dam of the reservoir. In the coal-pits there they drove to the east, and struck the Red rock fault just under where the feeder falls into the new branch of the canal. The Red rock is seen in the canal to be the lower subdivision of the New red sandstone, consisting of Red sandstones and conglomerates, and the coals are known to be in the lowest portion of the Coal-measures. So far we have seen no Permian rocks, though it is quite possible that rocks of that formation lie concealed under the New red sandstone, and between it and the Coal-measures on the downcast side of the great fault.

Nevertheless, no rock considered to be Permian makes its appearance at the surface between the New red sandstone and the lower rocks, till we come south of Aldridge to the neighbourhood of Hay Head and Great Barr, which has been before described.

Somewhere about the Brown Hill, however, it would appear that a split takes place in the boundary fault, and that a branch is sent off into the Coal-measures, ranging down the valley by Clayhanger, and thence to the southward, until it probably meets with or passes into the Linley and Daw End fault that cuts off the Walsall Silurian rocks.

The bottom Coal-measures crop, as before shown, all along the region of Pelsall Heath and the Brown Hills, dipping to the west. East of this outcrop, however, nothing is to be found but the red clays which are now believed to belong to the upper part of the Coal-measure series above all the workable coals. These may be seen lying horizontally or dipping at a very gentle angle to the northward or north-westward at Catshill, and all down by Walsall Wood to Stubbock's Green. From under these red clays the dark coal-bearing measures then rise to the southward towards Linley and Aldridge.

It appears certain that the coals which crop about the Brown Hills, and are known to be cut off by a fault there running north-north-east and south-sonth-west from Watling Street to the canal a little east of Birch Coppice, are thrown down under Clayhanger to a depth of more than 1,000 feet (300 or 400 yards), and that they lie at that depth under all Walsall Wood, forming the bottom part of the Coal-measures from which coals are now being got at the Coppy Hall colliery at Stubbock's Green, and that were proved to exist at the Aldridge Trial pits a little north of Red House.

It seems also certain that the Clayhanger fault must continue somewhere down by Goblins Pit Wood and Shelfield, towards Coal Heath, with a downthrow to the east.

It seems also quite certain that the abrupt northern termination of the limestones of Daw End and Hay Head along a certain line, with the equally abrupt coming in of Coal-measures immediately north of that line is the result of a fault having a downthrow to the north-east, and it is very probable then that the two faults thus proved to have a similar large downthrow, are in reality one fault, forming a branch of the boundary fault. If this be so the eastern boundary fault will form two step-like eastern downthrows from the Brown Hills to Hill End, south of Aldridge, while south of that it again becomes only one downthrow, but not of so large an amount, so that it allows the Permian rocks to appear at the surface on its eastern or downthrow side, instead of bringing down the New red sandstone to the level of that surface.

The Western Boundary fault.—If we begin on the south, we may say that the western boundary fault of the coal-field commences at the northern slope of Wychbury Hill. Thence to Oldswinford we have the Brick red sandstone and conglomerates on one side, and the upper Coal-measures on the other side of the fault. North of Oldswinford we get the Thick coal on the upcast side of the fault, cropping up against it and into it at an angle of 45° west of the "Grange," and on the downcast side we get a narrow band of Permian, soon overlaid by the base of the New red sandstone.

By Penn's Hill and Dennis to Audenham Bank, the beds below the Thick coal crop on the east of the fault, the Thick coal ranging up to it a little south of Brettell Lane, while the red rocks may be frequently seen at the surface just westward of the line drawn on the map.

Near Wordesley the New red sandstone dips at an angle of 20° to the west; the Permian, therefore, must here dip, at least, at as great an angle from the fault. At Bug Pool they sank through the fault down into the Thick coal below in consequence of the great overhanging ("hade," "overlie," "underlie," "inclination,") of the fault. In these pits they had 40 yards of "red rock," and got the Thick coal at 126 yards from the surface. Between Wordesley and Salters Hill, Mr. Bond sank 280 yards (840 feet) in the Permian rock at about 200 yards from its surface boundary, without passing through it into the Coal-measures. At the New Bromley Lane colliery south of the Stand Hills, Messrs. Davis have recently passed through the overhanging fault into the Coal-measures at a depth of 142 feet.

The junctions of the great faults called the Brockmoor, Corbyn's Hall, and Shut End faults with the Boundary fault (or perhaps we should say the separation of these great branches from it) appear to have little or no effect on its character. At Kingswinford the Brick red sandstone of the New red formation comes up against the fault, and we have that sandstone on the one side and the Coal-measures, with the Thick coal 140 yards (420 feet) deep, on the other. Before reaching Himley Park the boundary fault seems to split and let in

between its branches a wide tract of Permian rocks, occupying the eastern half of Himley Park, all Baggeridge Woods, and great part of Penn Common.

Indications of the extension of the west branch of this fault into the New red sandstone were observed as far as the Lloyd farm, by Mr. Beckett of Wolverhampton.

The main part or true boundary fault runs as drawn in the map, with a curved line up to Sedgley Hall farm; quarries or cuttings in the Permian rocks being observed at intervals all the way on one side, and Coal-measures on the other. At the turnpike-gate west of Sedgley some small pits in a patch of Thick coal were worked formerly, and in the year 1828 a trial pit was sunk just east of Sedgley Hall farm. In this trial pit the Thick coal was found at a depth of 323 feet, dipping to the west at an angle represented as only 12°. But as a quarry in the Permian rocks may be seen just north of the farm, and the limestone ridge rises immediately on the east of it, it is clear that there must be a fault on each side of this patch of Coal-measures. Moreover the first 120 feet in this shaft was described as "red croprash rock and marl," which were in all probability Permian rocks. From these facts it is probable that the boundary fault "hades" here, at a comparatively low angle, to the west, leaving a long space of "barren ground" between the ends of the Thick coal on opposite sides of the fault (see Horizontal Sections, Sheet 24, No. 6). This is probably the general character of the boundary fault in the southern part of its course. Along the flank of the Sedgley ridge all we know of the boundary fault is that there are Silurian rocks on the high ground on one side, and Permians in the valley below.

In the Parkfield coalworks beyond, as also in the Cockshutts and Green Lanes collieries, the Coal-measures are very violently broken and contorted,* and a very common feature is a rapid dip of the coal measures towards the fault as they approach it.

Patches of Thick coal were found in the shafts south of the Fighting Cocks dipping at the fault. Lord Ward's agent, Mr. R. Smith, informed me, that at one spot, after the Blue flats ironstone had risen to the surface in the form of an S from a depth of 100 yards, so that one shaft passed through the same measure three times, they sank a shaft a little farther west, in which, after passing through a few yards of "Red rock," they came down to some Thick coal, dipping west at a gentle angle, which they followed for a few yards till they found it cut off by another fault, hading rapidly to the west.

At a pit sunk in the Green Lanes, Wolverhampton, they found the Brooch coal at a depth of 30 or 40 yards (90 to 120 feet), dipping west at 2 in 3 (=34°), but as they sank deeper they found the dip of the beds increasing to 2 in 1† (=63°). This was very close to the line of the fault. At the tunnel of the railway at Wednesfield Heath the New mine coal cropped very gently up towards the fault for several hundred yards, and was exposed in the cutting of the railway.‡ Just at the east mouth of the tunnel they met with the "Red rock," dipping westerly, and the coal as it approached it was likewise seen suddenly to dip

* Not far from the Fighting Cocks a pit was sunk formerly where Mr. Pugh's house stands, in which pit the New mine coal, 6 feet thick, took 30 yards (90 feet) of perpendicular depth to traverse the width of the shaft, 7 feet. It dipped, therefore, at an angle of 81°.

† That is, in a seven-foot shaft, after passing through one measure on the crop side of the pit, they sank 14 feet deep before they left it on the dip side of the shaft.

‡ This is stated from my own personal recollection of the cutting at the time of the formation of the Grand Junction Railway.

towards the west, being much broken. The Blue flats ironstone, 160 or 170 feet below the New mine coal, was worked under the tunnel for nearly 100 yards beyond the end of the New mine coal, which would make the "hade" of the fault not much more than 30° from the horizon. At other places, however, between here and Wolverhampton, the fault seems from the workings to approach very nearly to a vertical. From Wolverhampton to within a mile and a half of Cannock, Permian rocks are believed to be those found below the surface on the downcast side of the fault; but at Wyrley Bank these rocks seem to be dying out, and beyond that the Brick red sandstone and conglomerate of the New red is alone seen. A split of the fault is thought to take place near the Walk Mill, one branch proceeding due north towards Stafford into the middle of the New red, while the other continues to form the boundary of the coal-field as far as Hednesford Pool, when that likewise so far dies out as to allow some of the beds of the New red sandstone to appear on the upcast side of it. The country is here so obscure that it is very difficult to say how this takes place—whether the fault becomes evanescent, or whether the beds of New red sandstone on opposite sides of it stood originally at very different levels in the formation.

The red clays of the Essington Wood brick pits are brought in apparently on this side of the coal-field, in the same way that those of Walsall Wood are brought in on the other. A split of the boundary fault as it ranges south seems to take place about Cheslyn Hey, the upper red Coal-measures making their appearance at the surface between the branch and the main boundary fault. The dip on this western side being to north-west, the black coal-bearing measures rise out to the southward towards the Old Mitre, just as they rise out towards Daw End on the eastern side of the coal-field, the downthrow of the branch fault decreasing in each case towards the south. It is possible that the branch on the western side, which we may call the Old Mitre fault, which is known to have a downthrow of 65 yards to the west thereabouts, runs on to the south till it is cut off either by the New Invention fault, or even till it reaches the extension of the Great Bentley fault.

Position and Lie of the Red rocks surrounding the coal-field.—We will now briefly recapitulate what we know of the Permian rocks surrounding the coal-field, and then describe the position of the beds of the New red sandstone around it.

Permian.—The Permian rocks in the narrow belt which runs S.S.W. from Cheslyn Hey towards Wolverhampton are covered towards the west by beds of conglomerate belonging to the New red sandstone, occasionally seen in situ; but still farther west, Professor Ramsay informs me that brown speckled sandstone (Permian) is seen at one or two places, especially in an old quarry a little to the N.E. of Bushbury Hill, and that the way in which these rocks appear involves the necessity of their being brought to the surface by faults having upthrows to the west, as drawn in the latter editions of the map and in Mr. Hull's Section, No. 45.)

Pale wine-coloured and nearly white sandstones, often highly calcareous, were exposed in the cuttings of the railways at Wolverhampton, dipping sometimes at an angle of 5° or 6° to the west. These were also believed to be Permian sandstones. Just

west of the road, however, near the windmill in Stafford-street, good brick red sandstone, certainly part of the New red, is well shown in a quarry, and appears to be quite horizontal. The new shaft for the waterworks at Goldthorn Hill is sunk entirely in mottled calcareous sandstones and marls of the Permian series. These were said to dip westerly across the shaft at an angle sometimes of 30° (Vertical Sections, Sheet 26, No. 50). On the crest of the hill to the westward are some gravel pits opened in the pebble beds of the New red sandstone, which likewise appear to have a slight westerly dip.

Indications of Permian beds on one side of the boundary and a gravel ridge (pebble beds of the New red) on the other are found from Goldthorn Hill to Penn Common. Permian marls and sandstones may be seen in the lower part of the brook south-east of the Lloyd House, and typical New red sandstone at the mill by the Wood-houses. Near Gospel End, the Permian beds, consisting of alternations of reddish and pale brown sandstones with red marls, and a band of slightly calcareous conglomerate, may be seen in some road cuttings. These Permian beds have everywhere hereabouts a dip of 5° or 10° to the west-north-west. A large mass of calcareous conglomerate, similar to that of Barnford Hill on the east of the coal-field, was found and mapped by Mr. Hull in Baggeridge Wood. At Hawkeswell Rough, north of Himley Park, good New red sandstone is seen apparently horizontal, while on higher ground to the eastward are two quarries of pale Permian sandstone, one of which dips north-east and the other south-east at 10°. A fault, therefore, must here separate the two formations. This is believed to extend northwards into the New red sandstone and southwards across Himley Park to the boundary fault. Just behind Himley Hall the conglomerates of the New red sandstone are well shown in a large cliff dipping north at 10°. Pale slightly calcareous sandstones may be seen about the Streights dipping north-west at 5°.

A narrow belt of Permian rocks just peeps out between the New red sandstone and the boundary fault between Kingswinford and Oldswinford. They consist principally of pale red calcareous sandstone and red marls. At Audenham Bank a concretionary mass of compact pale grey limestone, with a smooth conchoidal fracture, was exposed in the bank of the road lying in some red marl. It did not seem to extend far, however. Professor Ramsay informs me, that in a new road cutting near Dennis, Permian sandstones and marls containing slight traces of the trappean breccia may now be seen dipping west at 10° or 15°.

The Permian district round the south end of the coal-field is the largest and most important one of the neighbourhood, and worthy of a little more detailed description. When the country was first surveyed, no doubt was entertained that the Clent Hills consisted of trap rock, and that the angular fragments seen at the surface and in the small quarries were the local débris of the solid rock below. Professor Ramsay, who spent a day with me there in 1849, concurred in these views, which are those published by

Sir R. Murchison in his "Silurian System." On examining the Lickey Hills, however, it was soon perceived that the angular trap débris there rested on red sandstones, which had not then been separated from the New red sandstone formation. This trappean débris, therefore, was at first taken by myself for local drift, derived from the Clent Hills. In some places, however, it was seen apparently to pass under beds of the New red sandstone age, and therefore supposed there might have been a drift of it during the formation of that rock, and another of more recent epoch, deriving its materials either from the breccias of the New red, or directly from the Clent Hills, or partly from one and partly from the other. While examining some of these angular trap breccias, I was often led to entertain doubts as to their being really any trap *in situ* in the Clent Hills, but the trappean prestige was so strongly upon them that I did not venture to disturb it. The district indeed, though frequently traversed, was not then *surveyed*, as the "red rock" country was left till after the Coal-measures and older rocks were completed. Before even the coal-field was finished, I was called away (in 1850) to Ireland to assume the local direction of the survey there in consequence of my predecessor Professor Oldham's departure for India; and it was not till the year 1852 that I was enabled to return for a short time to complete my work sufficiently to allow of its publication. In the meantime Professor Ramsay and Mr. Hull had examined and made themselves masters of the Permian rocks, as shown in the North of Staffordshire; and Mr. Hull examined and partially surveyed the Permians round the South Staffordshire coal-field. Mr. Hull satisfied himself that the angular trappean breccia belonged to the Permian formation, and was a characteristic portion of it. In the spring of 1852 Professor Ramsay joined me in the district, when I had completed the examination of the coal-field; and we were soon aware that a more detailed and accurate survey of the Permian rocks round the south end of the coal-field was necessary. As I was compelled to go to London in order to make arrangements for the publication of this Memoir and free myself for what had become my more legitimate duties in Ireland, Professor Ramsay very kindly consented to devote some of his own time to the examination of this district; and the following are the results of this examination as he has provided me with them.*

The Clent Hills and Wychbury Hill (formerly considered to be trap, and coloured as such in my own working maps,) consist altogether, as far as their higher portions are concerned, of the angular trappean breccia, with no appearance of any trap *in situ* at all, "the fragments being principally composed of greenstone, with a little sandstone and a porcelanic looking slaty rock like some of those west of the Stiperstones." The beds are rudely stratified, and appear to dip south or south-south-west at an angle of about 5°. This angular trappean breccia may be traced con-

* I have entered on this personal detail in order that I may not seem to be taking more credit than I deserve, and also to strengthen my statements by the authority of Professor Ramsay.

tinuously from from Hagley Park to Broomsgrove Lickey, forming the uppermost of the Permian beds, having always a southerly dip, and passing in that direction under the "pebble beds" or conglomerates of the New red sandstone. The breccia is frequently a very deep red, the fragments being cemented together as it were by a red marly substance. When well exposed it is seen to pass insensibly at its base into red marls, the fragments getting smaller and finally disappearing.

Underneath this are red sandstones and marls, and then a band of highly calcareous sandstone comes in, showing itself under Square coppice at the Lickey, of the limeworks of Newtown, near Hunnington, near St. Kenelm's chapel, and west of the parsonage in Hagley Park. Near the latter spot the pebble beds of the New red appear to overlap the trappean breccia and approach the calcareous band,* running up nearly to the obelisk. They are then cut off by a fault which has been recently exposed in a new gravel pit, and the trappean breccia again comes out to form Wychbury Hill. A similar fault, bringing down the gravel beds to abut against the trappean breccia, is believed to terminate it at the Lickey Hill, just north of "the High House" (see Map). The lower beds of the formation, consisting of red and brown sandstones and marls, with one or two calcareous bands, spread over the country from Hagley Wood to Frankley, Kitwell, and the Lappal tunnel, the beds having, doubtless, a general slight inclination to the southward, with several minor flexures. Another patch of the trappean breccia caps the hill on which the well-known trees called Frankley Beeches stand.

From Frankley the dip appears to be south-south-east, and this inclination brings in the trappean breccia again in that direction, dipping in the lane north of Merrit brook at 20° to the south-south-east. Here all the Permian rocks are cut off to the eastward by a fault, believed to be an extension of the eastern boundary fault; and New red sandstone occupies the triangular district between Shenley Court and Weoley Castle. Brick red sandstone comes in south-east of the last-named trappean breccia, resting on it at one place apparently in a horizontal position, but in another appearing to dip from it at an angle of 15°. This sandstone, together with the Permian and other rocks between it and the Lickey, are all believed to be cut off by a fault running north-east and south-west, which will be described presently. From Frankley the Permian rocks extend northwards to the Lappal tunnel, and then, after being apparently interrupted by the Coal-measure tract running down to the Stonehouse, they occupy a broad band of country, extending northwards, between Oldbury and Smethwick, and thence by Great Barr to the ground between Barr Beacon and Hey Head. This Permian tract has already been described (pp. 11, 12, 177, and 178), when speaking of the Coal-measures as coal is worked through part of it.

* Unless this be the effect of a fault, a part perhaps of the boundary fault of the coal-field.

New red sandstone.—We have now very briefly to examine the position of the rocks forming the New red sandstone formation. The northern part of Cannock Chase consists of red sandstones and pebble beds belonging to the middle and lower portions of the New red. These rocks must dip very gently to the north-north-east, in which direction they pass under the upper red marls on the north side of the rivers Sow and Trent. Similar beds on the east side of the coal-field between Lichfield and Rugeley, having a similar dip, likewise pass under the red marls north of the river Trent. These marls, partly by the northerly dip of their beds, partly by the rise of the ground in that direction, become eventually capped by two large patches of Lias, the one occupying Bagot's Park and part of Needwood Forest, the other spreading round Christchurch on Needwood (see Map, Sheet 72, south-east). The sandstones under these marls rise to the westward also, and crop on the high ground between Ingestre and Stafford; but the bottom parts of the red marls are suddenly brought in again by a downcast fault, which is believed to be an extension of the branch that comes from the western boundary fault near Cannock. In consequence of this depression of the beds, the red marls spread themselves over all the country from Stafford to Penkridge and Brewood as far south as Wrottesley Park, and even to the south of that another patch of them is thought to be brought in by a fault, so as to cap the high ground between the Wergs and Nurton. From this point the middle and lower parts of the New red sandstone are seen to stretch uninterruptedly to the southward, till they are again covered by the red marls of Worcestershire a little south of Bellbroughton.

Between Cannock and Wombourne the general dip of those beds must be to the north-west, both from their passing under the red marls in that direction and from their allowing the Permians to rise from beneath them on the south-east.

From Wombourne to the neighbourhood of Stourbridge they probably scarcely deviate from horizontality, except where they rise to the eastward to allow the Permian beds to appear at the surface, or are tilted slightly on approaching the boundary fault of the coal-field. South of Hagley and Clent the general inclination of the New red must be to the southward, the pebble beds rising on to the flanks of the Clent Hills,* and the red marls setting in south of Bellbroughton and at Chaddesley Corbett, and Elmsley Lovett.† Between these places the red marls are underlaid by a white sandstone exactly similar to that under the marls near Albrighton and about Codsall, Brewood, Penkridge,

* The quartzose gravel or pebble beds of the New red sandstone about Clent and Calcot Hill rest directly on or against the angular trappean breccia of the Permian formation. Notwithstanding the incoherent and easily transported character of the materials of the two formations, their boundary is wonderfully distinct, so much so that it can be traced across ploughed fields merely by the nature of the pebbles and fragments lying on the surface, so little have these been mingled either during the deposition of the New red or at any subsequent period.

† From this to the end of the chapter is an account of the work done by Professor Ramsay, assisted by Mr. Howell.

and Rugeley. Plants were found in it by Professor Ramsay near Bellbroughton similar to those described by Sir R. I. Murchison and Mr. Strickland in their paper in the 5th vol. of the Geological Transactions.

These Worcestershire marls have a general south-easterly dip, which brings in the Lias east of Hanbury. My colleague, Mr. Howell, partly by himself and partly in conjunction with Professor Ramsay, had mapped the red marls continuously from the Lias of Needwood Forest, by Lichfield, Tamworth, and Birmingham, to Droitwich; and Professor Ramsay informs me that this Lias near Hanbury is precisely similar in mineral character to that of the outliers of Needwood in Staffordshire, consisting of "pale clay below, with interstratified beds of pale bluish argillaceous limestone, covered by brownish white, very thin bedded, micaceous sandstone, containing casts of small bivalve shells." The extension of this Lias to the eastward is cut off by an upcast fault running north-west, in which direction the red marls are themselves cut off to the east, and red sandstone brought up against them, probably by the same fault running generally north in a slightly curved line. It is not improbable that this fault runs much farther north, and is in some way connected with the western boundary fault of the coal-field. If so, we have strong presumptive evidence for a fault, running generally north and south with a downthrow to the west for upwards of 40 miles, or from the latitude of Stone to that of Droitwich (see Map, Sheets 72, south-west; 62, north-west and south-west; and 54, north-west).

The New red sandstone between Bromsgrove and the Lickey Hill has a general dip to the south-west and south, and the white sandstone comes in around Bromsgrove, passing under the marls to the southward of it. This white sandstone likewise contains fossil plants at Hill Top near Bromsgrove. It appears to pass laterally as well as downwards, into red sandstone. If we start from the natural boundary of the red marl, south of Bromsgrove, and walk across the country to the pebble beds of the Lickey Hill, a distance of about four miles, we should find that every exposed piece of rock showed a dip to the southward or south-westward, sometimes at an angle even of 10°. Whatever allowance we make, therefore, for undulations of the beds, we must necessarily suppose a very considerable thickness to interpose between the bottom of the red marls and the bottom of the pebble beds. If, however, we pass on to the east side of the Lickey quartz ridge, we shall find the natural boundary of the red marls coming up within a mile of the older rocks, and near Kendal end, within 100 or 200 yards of them. As the beds do not seem to have any greater amount of dip on the east of the quartz ridge than they have on the south-west, we must either suppose the whole of the red sandstone to have thinned out here, and the red marls to overlap nearly the whole of the lower beds, or a very considerable downthrow fault to traverse the east side of the quartz ridge. Moreover, the thick pebble beds lying on the south-west flank of the quartz ridge cannot be traced round its southern extremity, nor seen anywhere to the eastward. It is

probable, therefore, that they are concealed under the other beds there by means of such a downcast fault. Several other faults have been found affecting the margin of the red marls, as may be seen in the map.

We have already mentioned a south-west and north-east fault, supposed to start from the sides of the quartz ridge near the coal-measures, and run to the north-east. This has a downthrow to the south-east, and brings down the New red sandstone level with the ends of the Silurian, Coal-measures and Permain beds, between the Colmers and Mason's Lodge. Farther to the north-east it brings the red marl down against the lower part of the New red, namely, the brick-red sandstone, and it then runs off to the north-east through Birmingham, up nearly to Sutton Coldfield, bringing the red marls down against various parts of the New red sandstone. From the eastward of Sutton Coldfield the red marls stretch to the northward uninterruptedly to those before mentioned, north of the Trent, between Barton-under-Needwood and Abbott's Bromley.

The New red sandstone included between this marl boundary and the coal-field consists of brick-red sandstones near Birmingham, part of the upper Bunter sandstone, lying either horizontally, or dipping very slightly to the east, and allowing of the outcrop of a thickish band of pebble beds that usually form the boundary of the New red towards the Permian district. These pebble beds may be traced, more or less continuously, from the Lightwoods near Harborne to Barr Beacon. They apparently extend eastward a good way about Sutton Park, but they approach the boundary of the coal-field again about the Brown Hills, and coming against the fault are cut off by it, dipping north under the upper part of the New red, and only just rising up and re-appearing at the surface on the high ground west of Brereton, from which place they join on to those of the north part of Cannock Chase. Between Lichfield and Rugeley we have only the upper parts of the red sandstone, those lying just below the red marls as before described; so that if the ground were a little higher, the tops of the hills would all be capped by the red marl, as is the hill at the Old Lodge.

CHAPTER XIII.

On Faults.

The previous Chapters have been confined almost entirely to the description of facts actually observed. In the present Chapter it is intended to make some remarks on the proper use of the term "fault," and on some facts tending to throw light on the origin of faults and their mode of production.

The word "fault" is one of several that have been selected by geologists from the language of practical miners, and adopted as scientific terms. Various synonyms for it are used in different

districts. "Dyke" is the word most commonly used in the north of England, and "trouble," "slip," and other similar terms, often occur. In South Staffordshire the word "thing" is very commonly used instead of "fault." They speak of an "upcast" or "downcast thing."

I am not exactly aware how far "fault" and its synonyms may be used accurately in other mining districts, but in South Staffordshire both "fault" and "thing" are terms which are used by colliers, ground bailiffs, agents, and all concerned with them, in the most vague and puzzling way. These terms are applied to matters of the most incongruous natures, so incongruous that it is impossible to include them under any one general term without introducing great confusion of ideas, and consequently falling into all sorts of blunders in practice.

For instance, we have already seen that a cake of sandstone included in a mass of coal is called a "fault," and though in the preceding pages it has always been spoken of as a "rock-fault," yet that limitation or specification of its nature is not one commonly used in the district. Again, the "rolls" or "swells" in the floor of the coal are called "faults." Mere partial and irregular thickenings or thinnings of a bed are spoken of as "faults." I have even heard the natural outcrop of a bed of coal at the surface, especially if it rose to the crop a little more suddenly than usual, spoken of as "the fault" by many old miners of the district.

One of the most eminent and long experienced coal and iron masters of South Staffordshire gave, as his definition of a fault, on a legal examination, "anything which interrupted and deteriorated the coal." Under this definition dykes and intrusive masses of "green rock" (or trap) would be called faults.

A very intelligent ground bailiff once described to me a "sand fault," which I could not understand till I found it meant the outcropping of the New mine coal into a mass of drift at a depth of 90 feet below the surface.

Mr. Keir, in his account of the district, evidently applies the term "fault" not to the mere fracture and displacement, but to the *substance*, whatever it be, that comes in between the walls of the fissure, or the substance that is met with in place of the coal. This idea of a substance of a different kind from that expected seems to be the prevailing one attached to the word fault, for not only do they call "faults" things such as those above, but I have on several occasions had true faults, such as the Brockmoor or Corbyn's Hall fault, described to me as "not really a fault, but only *a slip*."

Examples of the great pecuniary loss and practical blunders likely to arise from this confusion of ideas might be easily accumulated. I will select two. In the case of the gap in the Thick coal at the Gower colliery, described in page 45, it is clear that whatever cause it was which destroyed the coal, that cause had ceased to act before the Cat heath, or the bed immediately above the Thick coal, was formed; yet the ground bailiff who described it to me was surprised that the fault did not affect the Brooch coal

150 feet above the Cat heath. He, knowing that true faults when found in one bed must necessarily affect all the beds above it up to the surface, and looking at this gap in the Thick coal as a fault, expected to meet a similar gap in the Brooch coal above. He of course, would never have recommended, therefore, any operations in search of this Brooch coal; and much of it might have been left behind if it had not been worked in the adjoining ground, and gradually followed by him over this space against his preconceived opinion as to the possibility of its occurrence.

Another case was a dispute between two gentlemen arising from the uncertainty as to whether "rolls" or "swells" could be considered faults or parts of faults, which involved an expenditure of several hundred pounds, and left the question still undecided.

A. let to B. the Thick coal under a certain tract of ground. This ground was known to be traversed somewhere by a large fault, although its exact place in the ground was not known. The Thick coal was to be got, at a rent of so much per acre, up to the fault wherever it might be, allowance being made for so much of the coal as was injured or diminished by the fault, or by *any branches or offsetts of the fault.* It was found, that in addition to the fault, the Thick coal was traversed by two "swells," "rolls," or "horse backs," (see *ante*, p. 52,) which ran side by side across a part of the ground, diminishing the thickness of the coal by cutting out a certain portion of the lower beds of it. These "rolls," or long ridges, were traversed obliquely by the fault, and it was contended by B., that they were *branches or offsets of the fault*, and he claimed compensation accordingly.

A., however, contended that they had nothing to do with the fault, that they were mere ordinary accidents to be expected now and then in coal mining; and if compensated for at all, were to be so on totally different grounds from those put forward by B.

There can be no doubt that if we construe the agreement technically, according to the only possible accurate definition of the terms, A. was right. It is clear that the "rolls" or "swells" existed before the deposition of the upper beds of the Thick coal, while the fault was produced not only after the deposition of those beds, but subsequently to the formation of the whole of the Coal-measures above them. The "rolls" were traversed by the fault just in the same way as all the other parts and portions of the whole formation were traversed by it, and as they existed long prior to the fault, clearly could not have been produced by it, or be anything like "branches or offsets of it." Owing, however, to the vague and uncertain use of the term fault, which is the "custom of the country," and the confusion of ideas in men's minds as to the real nature and origin whether of beds or faults, as much evidence, and from as respectable parties, was adduced on B.'s side as on A.'s, and the matter was ultimately compromised.

This matter is mentioned here thus prominently because it is clearly a practical point well worthy the attention of those engaged in all coal mining operations. Unless such common terms as that

of "fault" can be assigned a definite technical meaning, it is plain that their insertion into legal documents, agreements, &c., can only be the fruitful cause of error and dispute, leading to much useless expense, and possibly to much needless ill feeling.

The remedy for the correction of error both in practical operations and in legal agreements, depending on the proper understanding of the nature of faults, is obvious. It is that the ground bailiffs, mine agents, and surveyors, the men on whose word and authority these things mainly depend, should have the opportunity of acquiring larger and more accurate knowledge, and more correct ideas, as to the real nature of the matters they are engaged with. A comparatively slight acquaintance with the rudiments of practical and theoretical geology, such as might be acquired by any intelligent person from a few months' instruction from a competent teacher, would be sufficient to produce a perfect uniformity in all such men's opinions as to what was and what was not "a fault." Such instruction would enable every mine agent in future life to observe accurately, and to arrange and record his observations truly and methodically, so that all his subsequent experience would be applied in the right direction, instead of, as is too often the case, in the wrong one, and tend to increase his real knowledge, not to add to his misconceptions.

The South Staffordshire coal-field has been so thoroughly worked and explored, that a study of its faults and dislocations will add something of precision and completeness even to the knowledge of a professed geologist.

It is clear that a single fault, that is a fissure running along one straight or slightly curved line, can only produce a "throw" or dislocation of the beds along *a part* of its course. There must be a point in the fissure where the dislocation begins, from which it increases to a maximum, and another point where it gradually ends, and it is scarcely possible that the mere fissure will terminate at either of those points. Such a fault may be likened to a crack in a deal board which ends in the board each way before it reaches its extremity. It is evident that we can only elevate or depress a portion of the board on one side of the crack above or below the corresponding portion on the other side by pushing it in or near the centre of the crack, and causing that portion to bulge. The protuberance of the bulge will be greatest at this part, and gradually diminish each way to the points, where, though the crack may continue, the parts on opposite sides of it retain their relative position. Such "single-lined faults" are those that extend east and west across the part of the coal-field between Dudley and Bilston. Although single in the centre of their course, they often split into one or two small branches near their extremities. The dislocation may be increased by the measures on one side of the fault being bent up into a bulge along its course, while those on the other are bent down. We may, moreover, conceive it possible for the beds ranging along the fault to have more than one "bend" in them, and thus the amount of the throw to diminish and again increase; and if the beds on

opposite sides of the fault bend in opposite directions, the flexures may cross each other, and thus the fault apparently disappear, and again set on again along the same line.

If now, recurring to the deal plank, we were to make a cross cut to the crack before mentioned, it is obvious that by applying the requisite force near the junction of the two, we might permanently elevate or depress the included corner of wood. We should then have a representation of two faults, each increasing towards their point of intersection. Or if we continue the crack to the edge of the plank, which we may look on as a great boundary fault, we may bend one side so as to make the dislocation gradually increase from its commencement up to its termination. Of the latter case we have examples in the Corbyn's Hall and Brockmoor faults, that gradually increase their "throw" as they approach the western boundary fault.

It follows from the above considerations, that if there be only one or only two lines of fracture they must gradually diminish and end somewhere, and that the dislocated ground must have at least one place of maximum disturbance towards which *it bends down* either in one or several directions.

To have any piece of ground altogether elevated or depressed with regard to the whole of that surrounding it, it is necessary that it be bounded by at least three rectilinear faults, or by such an arrangement of curved fractures as amount in effect to three or more rectilinear ones.

These statements will, of course, be to the geometrician exceedingly simple, and scarcely worth making. The considerations involved in them, however, are sometimes hardly sufficiently attended to in geological surveying. One often sees a mere straight line representing a fault on a geological map, and sometimes is tempted to wonder what becomes of it, or how any mass of beds can be elevated or depressed in consequence of a single crack running through them. That such single-lined fractures do occur, however, the beds on one side bending down, while those on the other have remained stationary, or have perhaps bulged upwards, is proved by the occurrence of the east and west faults, before described, traversing the South Staffordshire coal-field.

The above considerations have to do with the longitudinal extension only of faults, but their vertical extent is equally worthy of study. This, however, is so wide a field that we shall only venture on a small portion of it, the subject of "Trough faults," and refer the reader for other parts of it to the papers of Mr. Hopkins in the "Cambridge Philosophical Transactions," vol. 6, and in the "Philosophical Transactions of the Royal Society of London," vols. 133 and 134, 1842–3, as also to a paper by Mr. Darwin, in the "Transactions of the Geological Society," vol. 5, p. 601.

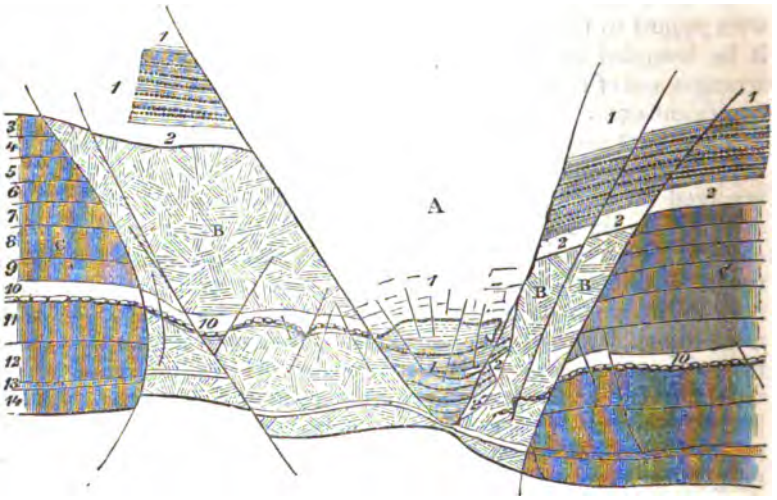
Of "Trough faults" we have several excellent and well-explored examples in the South Staffordshire coal-field, both on a large and small scale. We will take for examination one example of

each, namely, the Dudley Port Trough faults for the large scale, and a small pair of faults in the Victoria colliery, West Bromwich, for the other.

The Dudley Port Trough faults are shown in the section given in this volume (a reduction from No. 7, sheet 25, of the Horizontal sections), and their general form is reproduced in Fig. 28. They have previously been described (p. 164), to which the reader is requested to refer.

Mr. H. Johnson of Dudley, in the year 1849, showed me in his office a carefully-executed drawing of a singular appearance he had observed in the Thick coal in one of the gate-roads of the Victoria colliery at West Bromwich. At this spot the lower beds of the Thick coal were apparently unbroken and regular, but in the three upper beds there was a trough-shaped gap, eight feet wide at bottom and fifteen feet wide at top, in which reposed a corresponding mass of the beds that on either side lay on the topmost bed of the Thick coal. This gap in the coal gradually descended in one direction till it reached the bottom of the Thick coal, and assumed the form represented in the following figure:—

Fig. 26.



Scale, 1 inch equal to 20 feet.

A. Trough-shaped gap in the Thick coal.
B. and C. The Thick coal.
1. Shale and clunch above the Thick coal, containing some bands of ironstone nodules.
2. A black batt (bituminous shale).

Thick coal.
3. Roofs.
4. Top slipper.
5. White coal.
6. Lambs.
7. Tow coal.
8. Brazil.
9. Foot coal.
10. Hard stone parting.
11. Stone coal.
12. Sawyer and slipper.
13. Bench batt.
14. Benches coal.

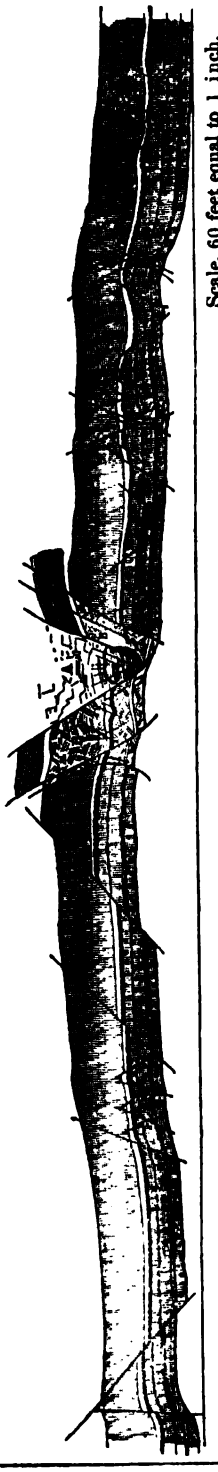


Fig. 27.

The triangular gap A in the Thick coal is filled up by a corresponding portion of the beds above the coal, consisting of shale and clunch, the lower part of which contains several courses of nodular ironstone, marked 1 in the figure. The strata in A are said to be "much broken and contorted, especiall towards the apex. The ends of the strata are turned a little upwards. Two pieces of bituminous shale (2) are found on one side of it, which should under ordinary circumstances occupy the top of the coal." These latter are shown near the right hand of the bottom of the trough in the figure, and marked (2). The trough traverses the coal in a north-east and south-west direction, the bottom of the trough forming an angle with the horizon of 4° 30′.

In the portion of the Thick coal marked C, the lamination and stratification of the coal is uninjured, but in the part marked B, while the stratification is for the most part probably unaltered, as is shown by the "partings 10 and 13 continuing through it almost uninterruptedly, the "lamination of the coal is totally destroyed, and the coal has the appearance of a paste made up of coal dust and very small coal. It appears to have attained its present consistency from compression and not from heat."*

Fig. 27 is a more extended representation of a side of the same gate-road on a smaller scale, that of 60 feet to the inch, its total length being about 150 yards. It is reduced from a much larger drawing of Mr. Johnson's, which was drawn to scale from very careful measurement, every fissure and flexure being as nearly as possible exactly represented.

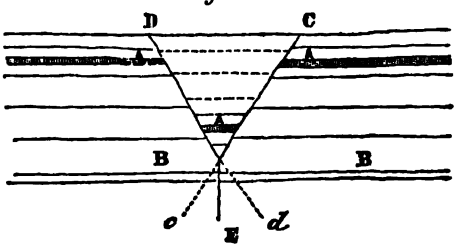
The two drawings given in Figs. 26 and 27 were taken, I believe, in consequence of the explanation I proposed to Mr. Johnson, to account for the appearance mentioned first (p. 194), that in which the trough did not end in a point downwards, but was still eight

* Mr. Johnson's notes.

feet wide at its base. The explanation then given was fully confirmed by these facts since observed and recorded by Mr. Johnson; and as it is applicable to all "Trough faults," and bears on the question of faults in general, it is now given here.

The simplest form of a Trough fault is that represented in Fig. 28, in which a portion of the bed A is dropped down between two

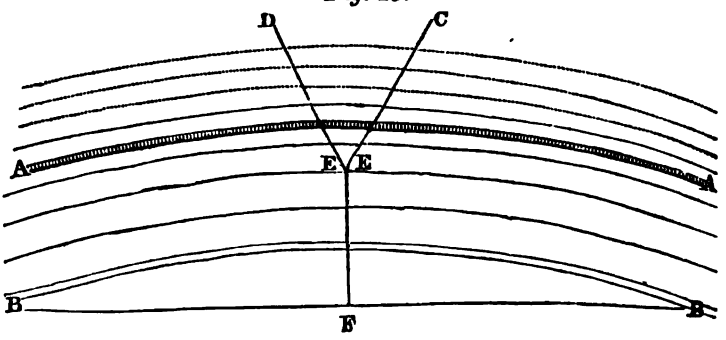
Fig. 28.



equal faults, C and D, which incline in such a manner that they must meet before reaching the lower bed B. It is clear that these faults, having an equal "throw" in opposite directions, must, when they meet, neutralize each other, and that no portion of the bed B can be "thrown" by them either upwards or downwards, or in any direction whatever. We may conceive it possible, however, that C may be continued as a fissure towards *c* or D similarly continued to *d*, though it seems much more likely that they should coalesce and continue in one intermediate fissure E.

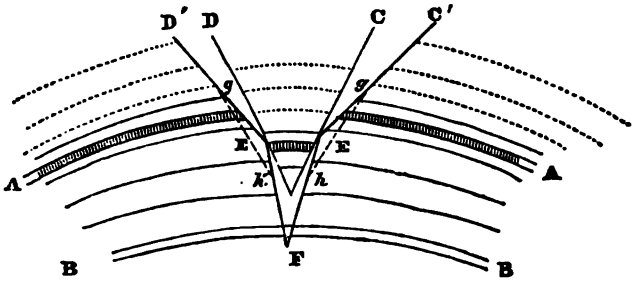
The most obvious explanation of the cause of such a condition of things seems to be the following. Let a set of beds of rock of indefinite extent, among which are two marked ones, A and B, be acted on by an elevating force from below, causing them to bulge upwards as in Fig. 29. Mr. Hopkins has shown us that if this expansion be continued far enough, the result will be the production of one or more longitudinal fissures, commencing at some point *below the surface.* Let such a fissure be produced running from F to E, and at E let it split into two, E D and E C.

Fig. 29.



Now, if the expansive force be continued, and a consequent further elevation take place, it is clear that the beds will assume the further form shown in Fig. 30, the two side portions being still more bent upwards, and the fissure consequently gaping open, so

Fig. 30.



that the lower single fissure F E widens into a triangular gap, and consequently E C spreads to E C′, and E D to E D′. In this case the included triangular mass of beds between D and C must fall down into the open fissure F E. Moreover, as for every inch that the parts A B rise and that E F widens, the included mass D C will settle down into it, the corners at E will be worn and ground down by the friction, so that they will very shortly be ground off to the lines *h g*, which will have the effect of still further widening the fissure, and consequently of admitting the wedge-shaped piece D C to sink further down into it.

Suppose now that the expansive and elevatory force ceases to act, and the upraised beds begin to settle down again towards a horizontal or nearly horizontal position, it is quite possible for the lower part of the fissure E F to close again, and to close in some cases so accurately and perfectly, that if the beds are at all soft and cohesive, scarcely a trace of it may be left after some period of compression. That part of the fissure, however, into which the wedge has sunk will, of course, not be able to close again, but it will strive to do so, and great force of compression will consequently be exerted on the sides of the wedge, and on the beds which come against them. The effect of this compression is shown in Fig. 26 in the destruction of the lamination in the coal marked B B. As, however, the beds sink into a very low arch, the downward pressure on the summit of the arch is made more and more of a horizontal thrust on its sides or abutments, the parts A and B on the sides of Figs. 29 and 30. When the arch becomes very low, the lateral pressure hereabouts must be enormous; and it is important to remark,* that we have here a real cause for bonâ fide *lateral pressure*, and consequent lateral shifting, and even of the sliding of one bed over the other, so that during the subsidence greater dislocations and more crumplings and contortions may take place at the outer ends of the arched beds, or at some distance outside of them, than took place in any part of the beds during the action of the elevating force.

Fig. 27 is an admirable instance of the arched condition of the beds, of the compressed central parts B B, and of the cracks and fissures that are likely to be caused on the sides of the arch as the

* This was remarked to me by Mr. Hopkins, in a conversation I once had with him on this point in the Museum of Practical Geology.

beds sink down again and are endeavouring to adjust themselves to their altered condition, consequent on the intrusion of the wedge A.

As all these actions may take place in nature simultaneously and very irregularly, according to a multitude of varying conditions, we may have a great number of modifications of the simple action here described. Among other things we may easily imagine the apex of the wedge to suffer considerably in some places, and to be ground off till it may have a blunt base, not only of 8 feet, but of many yards in width.

I have spoken before of the benefit Practical Mining might receive from the study of the science of Geology. This case is an instance of the great reciprocal advantage the science of Geology would receive from the observations of practical miners, if they knew what to observe, and how and where to record their observations. In the matter of faults and dislocations in the Coal-measures especially, there are many curious observations yet to be made, and many cases occur that would at first puzzle a geologist, and might be deemed by him impossibilities till he saw them before his eyes. Some of these came partially and imperfectly under my own observation when surveying this coal-field, but they could only be properly described and recorded by a person who was frequently engaged in measuring and drawing them during the progress of works extending, perhaps, over weeks or months.

We may, perhaps, here advantageously say a word or two as to the age of the principal faults and dislocations of the South Staffordshire district.

It is clear that, however the Silurian rocks may have been partially disturbed and denuded before the deposition of the Coal-measures, none of the prominent dislocations and disturbances which give the marked features to the structure of the district, took place till after the formation of the whole of the Coal-measure series. All the great faults, then, are of a later date than the deposition of the newest Coal-measures of the district.

How far the pre-existing rocks were fractured and disturbed at the *commencement* of the Permian period, or during the interval between the deposition of any Coal-measures and that of any Permians, is very difficult to be determined.

From considerations partly derived from this district, partly from other portions of the Midland Counties, it would appear probable that great disturbances, producing both large dislocations and an immense amount of denudation, took place some time during the Permian period, or some time between the period of the Coal-measures and that of the true New red sandstone. I should incline to look on it as possible that the disturbances along the line of the Lickey, and the Dudley and Sedgley anticlinals are of this date, and possibly also some of the principal faults of the coal-field. It is, however, plain, from the description given in the last Chapter, that the great boundary faults of the coal-field were, if not produced, at least largely acted on, subsequently to the deposition of the whole of the New red sandstone, and even to that of the Lias.

It is, of course, quite possible that the first impulse towards these faults, the strain that produced the cracks, was communicated to them at the period when the great disturbances in the Carboniferous rocks took place generally through Britain; and that period seems certainly to have been previously to the existence of the New red sandstone. A further subsidence or elevation, or in other words a relative displacement, may have at some subsequent period, or even at several periods, taken place among these cracks, extending them into the more recently deposited beds of the Red marls and the Lias, and "throwing" those rocks up or down from their original level, as we see to be the case with the Red marls on both sides of the coal-field, and with the Lias south of Bromsgrove.

No one, I think, will now be able to look at a geological map of the centre of England without connecting in his mind's eye the Lias of Worcestershire and Warwickshire with that of Staffordshire and Cheshire, and being convinced that these outlying patches once formed one broad connected sheet, a level plain of Lias spreading over all the intervening districts, and sweeping up into the borders of Wales. Wherever a sufficient thickness of the upper Red marls has been left undenuded, to render it possible for beds of Lias to come in, there we find them; but for the denudation, therefore, we should have found Lias wherever we now find the Red marls. The same reasoning will apply to the several members of the New red sandstone, down to the base of that formation. Wherever, therefore, the New red sandstone spreads (in the Midland Counties, at all events), it was in all probability once covered by Lias.

At all events, it is clear from our previous descriptions, and from an inspection of the maps and sections, that before the production of the dislocations of the great boundary faults, the New red sandstone spread over the coal-field and whole district of South Staffordshire, and we can see no reason why it should not have had the whole of its beds everywhere, or why these beds should not have been everywhere covered by the Lias.

At some subsequent period great dislocations took place, and either the present coal-field was lifted up above the surrounding district, or it was left standing while the surrounding districts were depressed, and thus rising as a great protuberance, was of course subject to the more marked influence, and more complete action, of the denuding agencies which have worn and pared down all the country to its present surface. In this way the lower rocks have been stripped of their former covering in the district forming the present coal-field, while more or less of that covering, according to circumstances, has been left untouched in the surrounding country.

The practical bearing of these remarks is this, that wherever we find any of the upper parts of the New red sandstone, we shall there, in all probability, find all the inferior ones in their proper position below it. To commence sinking for coal, therefore, in any of the parts coloured as Red marl in the geological maps of the Midland Counties, would be only to throw away money; still

more absurd would it be to attempt to find it by sinking in the Lias, as was formerly tried on Needwood forest.* It would even be a very imprudent speculation to attempt to sink for coal within any part of the New red sandstone district, unless it were first clearly ascertained that no great thickness of Permian rocks was likely to occur between the bottom of the New red sandstone and the top of the Coal-measures.

Supposing any one to be desirous of sinking for coal, either in the district between the South Staffordshire and Shropshire, or between the South Staffordshire and Warwickshire coal-fields, and assuming that Coal-measures stretch without interruption beneath, an assumption which the exposed area of the district described would not entirely warrant, he will have to calculate—

1st. The probable thickness of the beds of the New red sandstone he will have to pass through.—This will, in many places, be several hundred feet, let us say 500.

2nd. The possible or probable thickness of the Permian formation.—We have seen reason to suspect that this is in some places, perhaps in many, at least 500 yards, or 1,500 feet in thickness. He might be lucky enough to hit upon a spot where there was none of this; but there would be a great chance against such a piece of good fortune, and he would only act wisely to set this rock down as 1,500 feet thick.

3rd. The probable thickness of the upper and unproductive Coal-measures.—We have seen that in some part of the South Staffordshire coal-field there are 900 or 1,000 feet of Coal-measures above any of the workable beds of coal or ironstone. Our supposed speculator then would, in any place, have a great chance of coming first upon these upper measures, and would do well to calculate on the possible occurrence of 1,000 feet of them before he reached the more profitable beds.

We thus get altogether a total of 3,000 feet, or 1,000 yards, for the probable depth of good workable Coal-measures over the greater part of the space between the South Staffordshire coal-field and those of Shropshire on the one hand, or that of Warwickshire on the other, under the supposition above mentioned.

He must also take into account that after sinking for perhaps 1,000 or 2,000 feet (say 600 or 700 yards) through red rocks, he might find that he had come down upon a place where the Coal-measures are altogether absent, and might find himself penetrating Silurian shale or some other formation that lies below the coal.

* I may, perhaps, be pardoned for saying here, that even within my own recollection, since the year 1830 for instance, more money has been foolishly expended in the abortive search for coal alone, in places where a geologist would have at once declared against the possibility of finding it, than would have paid the entire cost of the Geological Survey from its commencement to the present time, or its future cost for many years.

Any search for coal through the lias or through the red marl could only be advisable in localities where those formations could be shown by geologists to have, probably or certainly, overlapped the Bunter and Permian beds, and to rest directly on the Coal-measures.

CHAPTER XIV.

On the Formation of Coal.

Coal is universally allowed to be of vegetable origin; it is a mass of the débris of trees and plants, that having been buried under mud and sand, has been subsequently converted into coal, the muds and sands being similarly converted into shales, and clays, and sandstones. There are, however, two opinions as to how the vegetables got into the situation we now find them in. The first, and at one time the more general opinion was, that trees and plants were drifted into large lakes, estuaries, and shallow seas, and there becoming water-logged, sank to the bottom, and were subsequently covered up there by the other accumulations. The second opinion, and perhaps the most generally entertained now, is, that the plants entering into the composition of the coal were not drifted, but grew and perished on the very spot we now find them forming coal, just as our own peat bogs at the present day would form coal if buried for a vast series of years under a great accumulation of earthy matters.

Botanists tell us that all the plants entering into the composition of coal, so far as they have been able to trace and verify any part of their structure, appear to have been not aquatic but terrestrial plants. For the formation of the beds of coal, therefore, *in situ*, it is necessary to suppose that the water in which the shales and sandstones were deposited became filled up, and the space converted into dry land, or, at all events, into a marsh at or above the level of the water; that on this dry land or marsh, plants accumulated in sufficient quantity to form a bed of coal; that then a depression took place, and the space became again covered by water, in which more shale and sandstone materials accumulated, again filling it up to the level of the water, and then another marsh, and so on.

I by no means intend to range myself among the advocates of either one or the other opinion, but I think there are certain difficulties in the way of the latter, which in spite of all the evidence as to the roots* and upright stems of trees, (or whatever the plants called Sigillaria, Stigmaria, &c. may have been,) would make me hesitate to embrace it exclusively. Some of these difficulties arise from facts observed in the South Staffordshire coal-field, and these it is now proposed to lay before the reader.

1st. *The "rolls," "swells," or "horse's backs."*—We have seen, page 52, Fig. 9, that these are long ridge-like accumulations

* Among other evidences is the case described by my friend Mr. Beckett, of Wolverhampton, in the first vol. of the Geological Journal. I afterwards accompanied him to the open work at Parkfields, where these stumps of plants occurred in the coal. They certainly looked as if they had grown there, and perhaps they may have done so, but even so, it by no means settles the whole question.

of clunch or clay rising for sometimes at least 8 feet above the floor of the coal around them. If they were accumulated under water, but the surrounding coal that abuts against their base was begun to be formed at or above the level of the water, we must necessarily suppose an elevation of the ground to have taken place to the amount of 8 feet, between the time of the formation of the "swells," and that of the coal, or else that they were formed during seasons of flood when the waters were 8 feet higher than usual. The structure of these "swells" seems to me a very small foundation on which to build the hypothesis either of a partial eight-foot elevation of the land, or for an eight-foot rise of the water. If, however, both "swell" and coal were formed under water, there is no difficulty in the case.

2nd. *The rock faults in the Thick coal.*—These were described pp. 45 to 51, Figs. 5 to 8. The most obvious questions to put respecting them, when we are inquiring into the origin of coal, are, if the sandstone was deposited in water, and the coal is so intimately and minutely interstratified with the sandstone, how comes it that the coal was not itself deposited in water? or, if the coal is of terrestrial origin, must not the sandstone be so too? The only possible origin * for the sandstone I can imagine on the latter alternative is, that the sand was brought up in among the vegetable matter by means of a strong spring or springs, but whether such an imagination be allowable to account for a mass of sandstone of 250 by 400 yards in extent, at least, must be left to the decision of the reader. There is, perhaps, at first a little difficulty in understanding this local accumulation of sand over a comparatively small area, surrounded by so much almost unmixed coal, even on the supposition of their both being drifted into the place we now find them, and deposited under some considerable depth of water, but in this case it is nothing more than the local occurrence of a cake of sandstone among wide spread beds of clay, or other material, a case which we know frequently occurs in nature.

More recent examination of the sand patches in the Thick coal of the Causeway Green colliery, and accounts of similar occurrences in many other parts of the neighbourhood, and the ending of the Thick coal in beds of sandstone in various directions, have only confirmed me in my belief in the entirely subaqueous deposition of those coals.

The way in which thick and thin seams of sandstone and coal alternated occasionally, with little seams of perfectly bright pure coal in the regularly stratified sandstone, while thick beds of pure bright coal are often flaked by little partings of clean sand throughout their thickness over considerable areas, seems to me to render it impossible to suppose otherwise than that their deposition and stratification was produced by the same agent.

It seems to me absolutely necessary to suppose that the vegetable matter was strewed out in regular thin laminæ at the bottom of

* It is clearly impossible it can have been "blown" sand.

some water, and that occasionally little clouds of fine sand or silt were carried into that water, and likewise sank to the bottom in fine layers. I have no doubt of the process of accumulation being a very slow and gradual one, for I have long been accustomed to look upon the time required for the formation of any wide spread bed of stratified rock whatever, even a single foot in thickness, as one to be measured only by the lapse of scores of years, perhaps by that of centuries. Each bed of coal is certainly made up of thin laminæ, which are obviously laminæ of deposition, every tenth or every hundredth of an inch requiring a distinct period for its production, as in the case of all other laminated rocks. The variations that take place in the quality and character of coals, sometimes inch by inch in their different laminæ, one being less and another more earthy, &c., the separation of the laminæ by little films of shale, or by thicker "partings" of substances that are distinctly argillaceous earth, more or less mingled with carbonaceous matter, those partings occasionally thickening out into substantial beds, and the occasional occurrence of nearly pure quartzose or micaceous sand, sometimes quite free from carbonaceous admixture, either in the thinnest films or in thicker beds, will all then be naturally accounted for by one process, namely, the gradual deposition of laminæ and strata of different kinds of substances, with different degrees of mingling at the bottom of some water.

3rd. *The phenomenon of the Flying reed.*—If the reader will turn to page 39, Fig. 4, he will see that to account for the structure there described, on the principle of all coal-beds being of terrestrial growth, the following suppositions are necessary:—Firstly, the water was filled up to its surface, and on that level plain the Heathen coal was formed, then a depression took place, and a subsequent refilling of the water with earthy deposits, and then the Thick coal was formed. When, however, the accumulation of the vast quantity of vegetable matter necessary for the production of the Thick coal was nearly completed, a very partial and local subsidence took place in one or two localities, bending down the previously formed beds into a hollow or pool of water, sufficiently deep for 128 feet of shale and sandstone to be accumulated, and thus another level floor formed for the growth of the upper bed of coal, which grew partly on the shale and sandstone, and partly on the undepressed coal. Then another depression took place, which was itself very unequal, and had this peculiarity, that over the part previously depressed it only amounted to 38 feet, while over the part not so depressed, and over the district generally, it was from 120 to 180 feet.*

4th. *The expansion of the Thick and other coals towards the north.*—When, however, we extend our observation beyond the

* It seems necessary to suppose that the depressions were unequal, and the irregularities levelled up to the surface of the water, by the accumulation of materials, because, if the depressions were equal over large spaces, and the accumulations of unequal thickness, we should be obliged to call in the aid of unequal elevations or depressions again, to form a level surface "à fleur d'eau," for the growth of the next bed of coal.

mere phenomenon of the Flying reed, and embrace that of the expansion of the whole Coal-measure series to the north, and the splitting up and separation of the coals in that direction, I must confess the idea of those coals being formed only at or above the surface of the water, while all the beds between the coals were deposited below the surface of the water, becomes one that I find it impossible to entertain. It will scarcely be worth while to go into an elaborate argument on this part of the subject, since I think an inspection of the diagram on Plate 1, p. 25, will be of itself sufficient.

It has been formerly pointed out from facts observed in this district, which are in perfect harmony with the well-known facts elsewhere, that single beds of stratified rocks have generally an area greater, and a thickness less, in proportion to the fineness of the materials of which they are composed. When the materials are coarse they are usually heaped together so as to form a thick bed in one place, which gets rapidly thinner in different directions, and often soon ends altogether. When several beds of the same kind of substance rest on each other, so as to form a group or set of beds, the above statement is almost equally true. When, on the other hand, the materials of which a single bed, or any set of beds, is composed are of very fine grain, those materials are generally equally diffused over a very wide area, changes in thickness are rare and occur very gradually, and the bed or set of beds where it comes to an end does so very gradually, and sometimes almost insensibly. When beds of coarse material are interstratified with beds of fine, the changes that take place in the grouping of the beds is often the result, solely or chiefly, of the changes in the coarser members, their sudden terminations, or their sudden thickenings and thinnings; the apparent changes in the thickness of the finer beds is due to single continuous beds or single continuous layers or laminæ being either separated by the partial interposition, or brought together by the partial absence, of the coarser over certain spaces. Now, it is clear that this law of the area of beds and laminæ being greater and their thickness less, in proportion to their fineness of grain, means nothing else than that the materials were spread over a larger space in consequence of their comparatively light specific gravity, or at least of their being more easily and therefore more widely transported by water, and being more generally diffused through it before finally coming to rest at the bottom. It was pointed out before too, that beds of coal so far from forming any exception to this general rule, are its most marked example at the one extreme, while coarse sandstones and conglomerates form the most striking example at the other.

In no Coal-measures that I ever examined in any part of the world, either in the British Islands, Newfoundland, or Australia could I ever detect anything but the most perfect conformity and blending between beds of coal and the stratified aqueous rocks in which they lay, the whole apparently forming one series of deposits produced by one agent acting in one way.

The diagram on Plate 1 confirms these views in perhaps as striking a fashion as could be imagined. The beds of coal are evidently continuous from the northern to the southern part of the field. Each layer of carbonaceous matter has been widely and generally diffused throughout the water on the bottom of which it was ultimately deposited. How it came there, whether it was altogether of extraneous origin and transported from a greater or less distance, or whether it was the result of the death and decomposition of vegetables that grew in the water and were rooted in its bed, or whether some of them grew and some of them were transported thither, or how else the carbonaceous matter came there, is a part of the subject on which I offer no opinion. I wish merely to say as the result of an experience of a good many years, confirmed by the particular instance under examination, that it appears to me that the phenomena of the lamination and stratification of beds of coal, and their interstratification and association with other stratified rocks, are explicable *solely by the relation of the specific gravity of their materials to the action of moving water*, and the consequent diffusion of those materials through the mass of that water.

We know that at all events the materials of the clays and sandstones were transported into that water at intervals, and it appears that in the case of the South Staffordshire coal-field, the principal and most abundant source of these materials lay to the north of the coal-field, and that these materials which were largely and frequently deposited on the north, sometimes failed to reach the more southern part of the area, while the coals were diffused equally, or at least more equally, over the whole area.

If, for instance, we were to examine the constitution of the Bottom coal, commencing on the north and following it to the south, we should learn the following facts respecting,—

First of all about the latitude of the Rising Sun at the Brown Hills, a great number of layers of carbonaceous matter were deposited until eventually enough was accumulated to form a thickness of 5 feet of coal. In whatever way this took place we cannot conceive it to have been otherwise than a long process. No one perhaps has yet formed an adequate conception of the vast length of time and great growth of vegetable life, either on the spot or in the neighbourhood, required for the formation of 5 feet of coal over an area of many square miles. There was then a gradual and successive deposition of several hundred layers of fine black mud forming more than 3 feet of dark shale. This bed is only 2½ feet thick at Pelsall, a mile or two farther south, but in one place becomes 9 feet thick in consequence either of some change in the currents or of some undulation in the bottom, or some other arrestation of the suspended materials. Farther south this bed is not mentioned at all, either because it does not exist at all or because it is too thin to notice. Near the Rising Sun we find over it another series of coal layers forming the Roof coal, which in one pit is a 10-inch and in another a 13-inch coal. At Pelsall, where the

bed below becomes thin, this coal swells out to 3 feet for a short space, while at High Bridge, where the swelling out of the bed below to 9 feet takes place, the coal thins again to 1 foot 9 inches. The deposition, like all other aqueous depositions, was evidently thicker where there was a hollow, and thinner where there was a rise, in the bottom. South of this point where the intermediate bed ceases altogether, the united coal layers continue southwards with a uniform aggregate thickness of 7 feet. Returning to the Rising Sun we find over the Roof coal (which together with the coal below and the intervening bed is spoken of there as the Deep coal) an accumulation of shales and sandstones varying greatly in the details of their grouping and thickness even in closely adjoining pits, but making an aggregate thickness of 41 feet 3 inches in one pit, and 48 feet 10 inches in another. This is in each case covered by the series of layers of coal called the Shallow coal, having an aggregate thickness of 6 feet. At Pelsall Wood the Shallow coal is only 4 feet thick, while the beds between it and the Deep coal are 45 feet, but at High Bridge the coal is 5 feet 2 inches, and the beds below are only 37 feet 9 inches.

From this point the two coals retain their thickness of 5 feet and 7 feet as they range southwards, but the beds between them rapidly thin out, and finally disappear about a mile and a half south of High Bridge. The two coals then come together to form a twelve-foot coal, and continue under the name of the Bottom coal with that thickness for a mile or two to the southward, when they also begin to get thinner and thinner, and finally die out in the district south of Dudley.

This instance, of which the details could be traced, if necessary, through various contiguous collieries in far greater detail, is only one instance of the many similar changes occurring throughout the Coal-measure series. These changes are distinctly referable to the action of water in transporting materials of different kinds that have been committed to it, and cannot, so far as I can see, be referred to any other agency.

If we look at the diagrams on Plate I., with the knowledge of these and similar facts fresh in our minds, and not with the view of extracting a merely possible explanation of it from conceivable circumstances, I think we cennot fail to be struck with the obvious "delta-like" or "bank-like" form which the Coal-measures of South Staffordshire must have originally possessed, and the perfect resemblance they must have had to an undisturbed subaqueous accumulation.

It seems to me then impossible to suppose otherwise than that the whole series of the Coal-measures, coals included, were deposited by one connected operation of the same forces acting in obedience to the same physical laws on similar but slightly differing materials, through an indefinite but immensely long period of time.

The Drift or Superficial Accumulations.

I have reserved to this place the little I have to say on this subject. This little consists of a few fragmentary notices rather than any connected account.

Blocks of granite and old trappean rocks, evidently belonging to the Great Northern drift, are found in great abundance all along the western boundary of the coal-field, especially about Bushbury, and thence towards Cannock. They occur abundantly also over all the New red sandstone country on the west of the coal-field. They may be found occasionally, but by no means abundantly, within the limits of the coal-field itself, but on its eastern side they are, as far as my recollection serves me, comparatively very rare. They are seldom found embedded in any great mass of drift matter, but lie for the most part loosely scattered over the surface of the country.

There is another set of drifted materials which I should be inclined to separate from the Great Northern drift, because large granite blocks are rarely, if ever, found in it, while it often abounds in chalk flints, and sometimes in broken fossils of the Lias and Oolitic formations, and seems, therefore, rather to be derived from the east than the north. This occurs in the shape of sand and gravel lying in patches here and there about the district, or sometimes as a red clay. Red clay, containing water-worn Lias fossils, is frequently found about Wolverhampton, or between that town and Shiffnal, on the cutting of the Shrewsbury railway, resting on the New red sandstone. A block of galena, also, as big as a man's head, was once procured from it near Wolverhampton. It never has been found, so far as I am aware, to contain any fragments of arctic shells, or of any other shells or fossils than those before mentioned as drifted out of other formations.

There is yet another class of drift, apparently distinct from both the above, as never containing any granite or northern boulders, nor any water-worn fossils or recognizable fragments of other formations. It consists, for the most part, of very fine red sand, with a few occasional lines or thin beds of very small well-rounded pebbles, principally of quartz or quartz rock. This occurs in immense quantity about West Bromwich and Hill top, in places between Darlaston and Walsall, and thence towards Willenhall and Pelsall. Large and deep excavations in it may be seen at Moxley Sand hole,* between Wednesbury and Bilston, whence it runs in a pretty well defined band, about a quarter of a mile wide, up to Marshend, a little east of Wednesfield. It makes no feature at the surface of the ground, but comes in suddenly 50, 60, or 100 feet deep, filling up a pre-existing valley in the Coal-measures, and causing great trouble to those who have to sink through it to the beds below. North-east of Wednesbury the New mine coal

* Some men working in these sand holes assured me that a stag's antlers had once been found in this drift at a depth of 40 or 50 feet below the surface.

suddenly crops into this loose sand at a depth of 90 feet below the surface of the ground.

This loose red sand seems to be the washing of the adjacent New red sandstone, and when it is a little consolidated, which it sometimes is, and only a small section of it is exposed, it is extremely difficult to distinguish it from undisturbed New red. This is especially the case about Pelsall and Pelsall Heath. I should class with this drift, in time and manner of accummulation, those quartzose gravel beds which do not belong to the New red sandstone, but which are derived from the washing of its "pebble beds" or conglomerates. These occur very abundantly in some places; they were well shown formerly in the deep cutting of the canal at Smethwick. They spread over all the southern part of Cannock Chase, resting on the Coal-measures there, having been brought probably from the undisturbed pebble beds or conglomerates of the New red, which form the northern portion of the Chase.

Whether these three sorts of drift all belong to one and the same period, that commonly known by the name of the glacial period, is a problem yet to be solved. I may be pardoned, perhaps, for saying that I think many geologists are too hasty in speaking of all superficial drifted materials as "*the drift*," as if there could only be one drift. We have already seen that there was both a Permian and a New red sandstone drift, portions of which, when they appear isolated at the surface, would be taken by any one for parts of the "glacial drift," at first sight.

I know of no reason, for instance, why the drift clay, and sand and gravel containing Chalk flints and Lias fossils, might not be of the age of the gravels of the Plastic clay, though I am not at all disposed to assert that they are so, because, as I know of no evidence against such supposition, neither do I know of any reason for it.

If it be true that stags' antlers were found under the red sand at Moxley, it would, of course, be a proof of its comparatively recent origin; but in the absence of that or some such proof, I should hold myself prepared to find that these sand and gravel washings of the New red sandstone were of any age from that of the Oolites down to the Pleistocene.

CONCLUSION.

No one can be more sensible than myself of the deficiencies of the preceding pages. The work was executed on the Ordnance map of the scale of one inch to the mile, there being no other of similar accuracy on a larger scale. A more detailed survey might have been made had there been a map on the scale of six inches to the mile, such as that of the Townland Survey of Ireland (by the

aid of which the geological survey of Ireland is carried on), or the similar map now in progress in the north of England. Such maps show every natural and artificial feature on its proper scale, and leave room for the insertion of all the requisite data in a distinct form, and without any distortion.* With such a map it would have been possible to have had a separate survey of the Thick coal, showing its depth below the surface at any locality, the nature and magnitude of the faults traversing it, and the extent of injured coal or barren ground caused by them; the places where the coal was injured by trap rock, and the amount of the damage; the districts, such as the large swamp in the centre of the coal-field, where it is now under water, the probable area and depth of that water, and consequently the power necessary to drain it; the spaces over which the Thick coal has been either partly or wholly extracted, and those where it is still untouched; and all other needful and useful information respecting it might thus have been brought together in a compendious form of the highest importance and utility to the practical miner. Every other important bed of coal and ironstone could have been laid down on its separate map, showing its extent, depth, thickness, richness, and the places where it had and where it had not been gotten.

Every one who has had anything to do with coal mining, even as a spectator, must be aware of the great waste of money, labour, and materials, consequent on the division of property among many small owners, each having different and opposite interests. Were the South Staffordshire coal-field now untouched and the property of one individual, there is no doubt that, as far as the mere economical extraction of its minerals is concerned, it might be worked under one well-considered system with infinitely less cost and far greater profit than it has been. The subdivision of property has, of course, great advantages on its side to counter-balance this disadvantage; but the carrying out such a survey as that I have named, while it would not at all interfere with the advantages arising from the subdivision of property, would render it possible to avoid all or most part of the disadvantage, because every one would know the exact state of the ground around him, and mutual agreements might thus be entered into as to the time and method of each working his own piece of land to the best advantage.

In the meanwhile it is hoped that the present general survey of the South Staffordshire coal-field will be found of considerable practical utility, since it has enabled us to combine into a general view much information that had hitherto been only scattered piece-meal about the district, to give a little more definite and common direction, perhaps, to the ideas hitherto floating loosely in many men's minds, as also to warn men off the districts where

* After some years' experience in working on the 6-inch map of Ireland, I can speak authoritatively as to the importance and value of such a map for geological surveys.

costly speculations will be almost sure to be unrewarded, and in some degree to point to those where they are most likely to be successful.

In conclusion, I have to make my acknowledgments to my many kind friends in South Staffordshire for much assistance, without which the survey could never have been rendered so accurate and complete even as it now is. I never made a single application to any landowner, coalowner, or ironmaster of the district, or to their agents, ground bailiffs, and men of business, for any species of information, that was not instantly and courteously responded to in the most ample manner. To enumerate the names of persons I have been thus indebted to would be to give a list of a large part of the population of the district; and is therefore obviously impossible. It is, however, only justice to state, that when the survey of the district was commenced, several of the principal faults traversing it had been laid down on large parish maps by some members of the Dudley Geological Society. Messrs. W. Sparrow and H. Beckett had done this for the district between Wolverhampton, Walsall, and Wednesbury, and Messrs. S. H. Blackwell and C. Twamley for the district around Dudley. The results of their labours were freely communicated, and after being verified, are now published in our maps. Several other gentlemen have been mentioned by name in the preceding Memoir as having afforded important information, and many more might have been mentioned, but that the information they so kindly gave became worked into the general account of the district, and did not relate to any particularly prominent and salient points of its structure.

APPENDIX.

In speaking of the inclination of a bed, or of a fault, or any other plane, it is common in South Staffordshire to describe it by saying how many inches it deepens, or dips, in a yard. In many other districts this is done by saying how many feet or yards it dips or inclines in the hundred. Geologists usually describe the dip by stating the number of degrees of the angle included between the plane of the bed, &c. and the plane of the horizon. It is often very useful in field surveying to know at once, roughly, how these things correspond, for which purpose I wrote out the following table for my own use, and add it here, as it may be useful to others :—

Nearest degree of dip, or each 1 in 100, answering to each inch in a yard.

Inches in a yard.	In 100.	Nearest degree.	Inches in a yard.	In 100.	Nearest degree.
1	2·78	1½°	19	52·82	28°
2	5·56	3°	20	55·60	29°
3	8·34	5°			
4	10·12	6°	21	58·38	30°
5	13·90	8°	22	61·16	32°
			23	63·94	33°
6	16·68	10°	24	66·71	34°
7	19·46	11°	25	69·50	35°
8	22·24	12°			
9	25·02	14°	26	72.28	36°
10	27·80	16°	27	75·06	37°
			28	77·84	38°
11	30·50	17°	29	80·62	39°
12	33·36	19°	30	83·40	40°
13	36·14	20°			
14	39·92	21°	31	86·18	40½°
15	41·70	23°	32	88·96	41°
			33	91·74	42°
16	44·48	24°	34	94·52	43°
17	47·26	25°	35	97·30	44°
18	50·04	26°	36	100·00	45°

When the inclination is greater than 45° it is commonly sufficient to say that a bed, &c. dips two yards in a yard, three yards in a yard, &c., &c.

Now 1 in 1 = 45°
2 in 1 = 63° nearly.
3 in 1 = 71° nearly.
4 in 1 = 76° nearly.
&c. &c.

Another way of describing the inclination of the beds is also not unfrequently used, namely by saying that they dip at the rate of one

yard or foot in so many yards or feet. The following table gives the latter number for each of the angles mentioned.

Angle of dip.	Incline of	Angle of dip.	Incline of
1°	1 in 57	8°	1 in 7
2°	1 in 29	9°	1 in 6
3°	1 in 19	11°	1 in 5
4°	1 in 14		
5°	1 in 11	14°	1 in 4
		18°	1 in 3
6°	1 in 10	26°	1 in 2
7°	1 in 8	45°	1 in 1

Another table that is often found useful in geological surveying is one that for every degree of dip of a bed, &c. will give its depth from the surface (supposed to be a horizontal plane) at a distance of 100 feet or yards, measured in the exact direction of the dip. In the following table this is given for every degree up to 20°, and for every five degrees after that; and also the thickness of any set of beds thus inclined, measured, not perpendicularly to the surface but perpendicularly to the dip, in other words, the thickness they would have if they were horizontal.

Horizontal distance = 100.

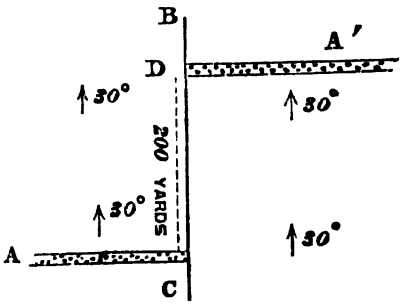
Angle of dip.	Depth.	Thickness.	Angle of dip.	Depth.	Thickness.
1°	1·7	1·7	18°	31·8	30·9
2°	3·5	3·5	19°	34·5	32·6
3°	5·3	5·3	20°	36·6	34·2
4°	7·0	7·0			
5°	8·8	8·7	25°	46·9	42·3
			30°	58·0	50·0
6°	10·6	10·5	35°	70·5	57·4
7°	12·3	12·2	40°	84·2	65·6
8°	14·1	13·9	45°	100·0	70·7
9°	16·0	15·6			
10°	17·7	17·4	50°	119·0	76·6
			55°	143·0	81·9
11°	19·5	19·1	60°	174·0	86·6
12°	21·4	20·8	65°	214·0	90·6
13°	23·2	22·5	70°	275·0	94·0
14°	25·2	24·2			
15°	26·9	25·9	75°	368·0	97·0
			80°	575·0	98·0
16°	28·7	27·6	85°	1143·0	99·0
17°	30·7	29·2			

As this table is one giving the solution of a right-angled triangle for each angle specified, it may be readily used to find any dimension which can be stated in the form of a right-angled triangle, as for calculating the space between the outcrop of two beds, of which the angle of dip is known and the thickness between them; the distance which any bed, of which the depth and inclination are known, will require before its outcrop at the surface can occur; and so on.

By means of this table, also, the probable "throw" of faults can be ascertained, where the broken ends of a bed on opposite sides of a fault

can be found, and a certain mean angle of dip assigned to the whole mass.

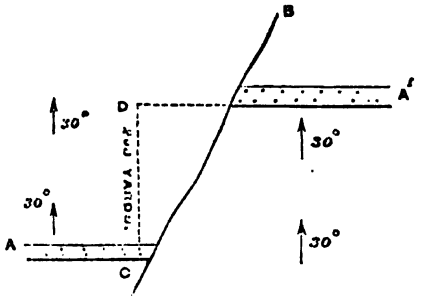
Fig. 31.



If, for instance, Fig. 31, there be a set of beds, including one particular bed A A′ dipping at 30° in one direction, traversed by the fault B C running in the direction of the dip, and the ends of the bed A A′ on opposite sides of the fault be any distance apart, say 200 yards, then, inasmuch as the bed A would by the table be twice 58=116 yards deep at D on one side of the fault while it is at the surface of the ground (supposed to be a horizontal plane) on the other side of the fault, it is obvious that the fault B C has a "downthrow" of 116 yards towards D.

If the fault traverse the beds obliquely to the strike, as in the following figure—

Fig. 32.



—we must, instead of measuring along the fault B C, of course, measure A D along the dip, and then proceed as before.

Conversely when the amount of the throw of any fault, and the angle of inclination of the beds, are known, if the place of the bed on one side of the fault be ascertained, that of its outcrop on the other side of the fault may be calculated, and so on.

Oblique Sections.

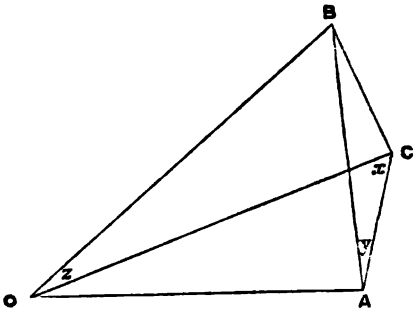
Although it has no especial reference to the district of South Staffordshire, I would yet take this opportunity of printing and publishing the additional table below.

In the year 1850 we were engaged in running sections across a very contorted district of North Wales, so contorted that it was impossible to contrive any long continuous section that should not in some part of its course cross both beds and cleavage planes very obliquely. It became important, therefore, to know what correction to apply to the observed angle of dip of those beds and planes, so that they should be

drawn in the sections correctly with the dips they would actually appear to have in a vertical cliff if one were formed along the line of section. Although the little trigonometry I ever possessed had long grown rusty from disuse, I yet contrived to puzzle out a formula which should express this correction, and from that calculated the table.

Subsequently, however, I lost the clue which had led me to the results, and became doubtful as to their correctness; I therefore applied to my friend Mr. Hopkins, then President of the Geological Society of London, and he, with his usual kindness, favoured me with the following solution of the problem, which I was glad to find gave the same result as that at which I had arrived by a more roundabout and empirical course.

Fig. 33.



Let O A be a horizontal line on the surface of a bed, it will be the direction of the strike: O C the direction of the section as given by the compass, O C being also horizontal.

Draw A C in the same horizontal plane as O A and O C, and at right angles to O A, A C will be the direction of the dip as given by the compass.

Draw C B, *vertical*, to meet the surface of the bed in B, and join A B and O B.

The angle C A B will be the real dip, and C O B the apparent dip, of the bed, as seen in the face of the supposed cliff or section.

Let O C A $= x$, the angle which the section makes with the direction of the dip,

C A B $= y$, the real dip,

C O B $= z$, the apparent dip,

$$\text{then tan. } y = \frac{\text{B C}}{\text{A C}}$$

$$\text{but B C} = \text{O B sin. } z$$

$$\text{and A C} = \text{O C cos. } x = \text{O B cos. } z \text{ cos. } x$$

$$\therefore \text{ tan. } y = \frac{\text{tan. } z}{\text{cos. } x} = \text{tan. } z \text{ sec. } x$$

or to radius r

$$(1)\ r \text{ tan. } y = \text{tan. } z \text{ sec. } x$$

and $\therefore$ log. tan. y = log. tan. z + log. sec. x − 10;

$$(2) \text{ or tan. } z = r\frac{\text{tan. } y}{\text{sec. } x}$$

$\therefore$ log. tan. z = 10 + log. tan. y − log. sec. x.

(1) Giving the *true* dip if the apparent dip were observed in a cliff.

(2) Giving the *apparent* dip that ought to be drawn in the section when the true dip is known.

From this formula the following table has been calculated:—

Oblique Section Table.

Angle between the direction of the dip and that of the section.	Angle of the Dip.																
	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	89°
10°	9° 51′	14° 47′	19° 48′	24° 40′	29° 37′	34° 36′	39° 34′	44° 34′	49° 34′	54° 35′	59° 37′	64° 40	69° 43′	74° 47′	79° 51′	84° 56′	88° 59′
15°	9° 40′	14° 31′	19° 23′	24° 15′	29° 9′	34° 4′	39° 2′	44° 1′	49° 1′	54° 4′	59° 8′	64° 14′	69° 21′	74° 30′	79° 39′	84° 50′	88° 58′
20°	9° 24′	14° 8′	18° 53′	23° 39′	28° 29	33° 21′	38° 15′	43° 13′	48° 14′	53° 19′	58° 26′	63° 36′	68° 49′	74° 5′	79° 22′	84° 41′	88° 56′
25°	9° 5′	13° 39′	18° 15′	22° 55′	27° 37′	32° 24′	37° 15′	42° 11′	47° 12′	52° 18′	57° 30′	62° 46′	68° 7′	73° 32′	78° 59′	84° 29′	88° 54′
30°	8° 41′	13° 4′	17° 30′	22° 0′	26° 34′	31° 14′	36° 0′	40° 54′	45° 54′	51° 3′	56° 19′	61° 42′	67° 12′	72° 48′	78° 29′	84° 14′	88° 51
35°	8° 13′	12° 23′	16° 36′	20° 54′	25° 18′	29° 50′	34° 30′	39° 19′	44° 19′	49° 29′	54° 49′	60° 21′	66° 3′	71° 53′	77° 51′	83° 54′	88° 47′
40°	7° 41′	11° 36′	15° 35′	19° 39′	23° 51′	28° 12′	32° 44′	37° 27′	42° 23	47° 35′	53° 0′	58° 40′	64° 35′	70° 45′	77° 2′	83° 29′	88° 42′
45°	7° 6′	10° 4′	14° 25′	18° 15′	22° 12′	26° 20′	30° 41′	35° 16′	40° 7′	45° 17′	50° 46′	56° 36′	62° 46′	69° 14′	76° 0′	82° 57′	88° 35′
50°	6° 28′	9° 46′	13° 10′	16° 41′	24° 21′	24° 14′	28° 20′	32° 44′	37° 27′	42° 33′	48° 4′	54° 2′	60° 29′	67° 22′	74° 40′	82° 15′	88° 27′
55°	5° 46′	8° 44′	11° 46′	14° 58′	18° 19′	21° 53′	25° 42′	29° 50′	34° 21′	39° 20′	44° 49′	50° 53′	57° 36′	64° 58′	72° 55′	81° 20′	88° 15′
60°	5° 2′	7° 38′	10° 19′	13° 7′	16° 6′	19° 18′	22° 45′	26° 33′	30° 47′	35° 32′	40° 54′	46° 59′	53° 57′	61° 49′	70° 34′	80° 5′	88° 0′
65°	4° 15′	6° 29′	8° 45′	11° 9′	13° 45′	16° 29′	19° 31′	22° 55′	26° 44′	31° 7′	36° 12′	42° 11′	49° 16′	57° 37′	67° 21′	78° 19′	87° 38′
70°	3° 27′	5° 14′	7° 6′	9° 3′	11° 10′	13° 26′	16° 0′	18° 53′	22° 11′	26° 2′	30° 39′	36° 15′	43° 13′	51° 55′	62° 43′	75° 39′	87° 5′
75°	2° 37′	3° 58′	5° 23′	6° 53′	8° 30′	10° 16′	12° 15′	14° 30′	17° 9′	20° 17′	24° 8′	29° 2′	35° 25′	44° 1′	55° 44′	71° 20′	86° 9′
80°	1° 45′	2° 40′	3° 37′	4° 37′	5° 44′	6° 56′	8° 17′	9° 51′	11° 41′	13° 55′	16° 44′	20° 25′	25° 30′	33° 57′	44° 33′	63° 15′	84° 15′
85°	0° 53′	1° 20′	1° 49′	2° 20′	2° 53′	3° 30′	4° 11′	4° 59′	5° 56′	7° 6′	8° 35′	10° 35′	13° 28′	18° 1′	26° 19′	44° 54′	78° 41′
89°	0° 10′	0° 16′	0° 22′	0° 28′	0° 35′	0° 42′	0° 50′	1° 0′	1° 11′	1° 26′	1° 44′	2° 9′	2° 45′	3° 44′	5° 39′	11° 17′	44° 59′

The use of this table is obvious without much explanation. A single example will suffice. Suppose a section be drawn running north-east and south-west, and it crosses certain beds dipping north at 35° (or certain cleavage planes, or a vein, or a fault, or any other plane having that dip), what angle ought we give to those beds in the section in order to give a true representation of the apparent dip they would have in a cliff running parallel to the section ?

In this case the angle between the direction of the dip and that of the section, or between north and north-east = 45°, which we look for in the vertical column on the left of the table, the angle of the dip =35°, which we find in the horizontal column at the top of the table. At the intersection of these two lines in the body of the table we should find 26° 15′, the angle required.

In practice the minutes of the angle are never required, but as it involved no extra trouble to insert them they are given, as the table might possibly be of use in other ways where more minute accuracy is requisite.

It is plain that the table can be equally used to find the *true* dip where the *apparent* dip only can be observed in a real cliff, provided the angle between the line of section and the strike (and therefore the direction of the true dip) of the beds can be ascertained. This, however is a case which rarely occurs in practice. When it does, of course the nearest angle to the observed apparent dip will be sought in the body of the table, on the line opposite to the angle between the direction of the cliff and that of the strike $\pm$ 90°, and the angle of the real dip answering to it will be found at the top of the table.

Note on the Stigmaria Beds of the South Staffordshire Coal-Field. By Sir Henry de la Beche, C.B., F.R.S., &c.

The coal-field of South Staffordshire forms no exception to the other coal-fields of Great Britain as regards the occurrence, in certain of its beds, of the peculiar fossil roots known as *Stigmaria*, in their relative places of growth. These vegetable remains, long considered as the stems of a distinct fossil plant, are now known, chiefly through the researches of Mr. Binney* in England, and of Mr. Brown† in Nova Scotia, to be the roots of the fossil genus *Sigillaria*, or of some other of the like kind of plants.

Mr. Steinhauer would appear (in 1818) to have been the first to have observed the mode of occurrence of *Stigmaria* in certain beds of the coal measures, in a manner pointing to their growth in the bed where they are thus found. Speaking of the rootlets or fibres, as he terms them, diverging from the main *Stigmaria* root, he remarks that "on examining

* Mr. Binney's observations respecting the trees discovered at St. Helen's, Lancashire, were made known to the meeting of the British Association for the Advancement of Science, in June 1845, and his description of the *Sigillaria* terminating in *Stigmaria*, found at Duckinfield, seven miles east of Manchester, was read before the Geological Society of London, in April 1846, and published in their Quarterly Journal, with figures, vol. ii. p. 390.

† Mr. Brown read a paper before the Geological Society, on the same day (22nd April 1852), with Mr. Binney's last-mentioned paper. It is also published in that Society's Journal, vol. ii., and is entitled "On a Group of Erect Fossil Trees, in the Sydney Coal-field at Cape Breton." He gives figures of an upright *Sigillaria* stem with branching *Stigmaria* roots.

the projecting ends of some trunks (of *Stigmaria*) which lay horizontally in a bed of clay, extending along the southern bank of the rivulet which separates the townships of Putsey and Tong, and which is exposed in several places, it excited no little surprise to find traces of these fibres proceeding from the centre cylinder in rays through the stratum in every direction, to the distance of twenty feet." He further inferred that these fibres or rootlets "belong to the trunks in question, and, consequently, that the vegetable grew in its present horizontal position at a time that the stratum was in a state capable of supporting its vegetation, and shot out its fibres in every direction through the then yielding mud."*

Though the evidence on this head is common to all the coal-fields of Great Britain, and can be so readily obtained in many localities, the subject did not engage much attention until Mr. William Edmond Logan,† examining the coal measures of Glamorganshire and Carmarthenshire, was not only enabled to confirm the views of Mr. Steinhauer, but also to ascertain (in 1833) the important fact that all the coal-beds of that district reposed on such beds. When the Geological Survey entered upon the examination of the Coal-measures in the vicinity of Swansea in 1837, Mr. Logan pointed out the *Stigmaria* beds as constantly beneath the coal.‡ In verifying the beautiful maps and sections of the western portion of the South Welsh coal-field, which, with a generous love for the advancement of knowledge, Mr. Logan presented to the Geological Survey, and which were subsequently published by it, abundant opportunities were afforded for ascertaining the truth of this view, one still further confirmed, as might have been anticipated, by the general examination of the whole coal-field of that portion of Great Britain. The Survey in its progress among many other coal-fields of the country, has always observed similar facts, and hitherto, including South Staffordshire, the connexion between coal and *Stigmaria* beds has, with few exceptions, and many of these doubtful, been found constant.

Having had occasion to visit nearly all the Coal-measure districts of Great Britain, from those of Scotland on the north to those of Somersetshire on the south, inclusive, I twice visited the South Staffordshire coal-field, and in all the cases where opportunities were afforded for examining the beds beneath the coal, found *Stigmaria* in them occurring as in their relative places of growth. Dr. Joseph Hooker in 1847, (then botanist to the Geological Survey,§) having directed his attention at that time especially to the structure of *Stigmaria*, and having had occasion, therefore, to examine into the subject with much detail, found these *Stigmaria* beds common ; ‖ Mr. Dawes, of Southwick House near Birmingham, who has given so much attention to the fossil botany

* American Philosophical Transactions, new series, vol. i.

† Now Sir W. E. Logan, Director of the Geological Survey of Canada.

‡ It was not until February 1840 that Mr. Logan communicated his knowledge of this circumstance to the Geological Society of London, in a paper entitled "On the Character of the Beds of Clay immediately below the Coal-Seams of South Wales, and on the Occurrence of Boulders of Coal in the Pennant Grit of that District." This memoir was published in the Transactions of that Society, vol. vi., 1842.

§ An appointment held by Dr. Hooker until his Botanical Mission, for the Government, to India, towards the end of 1847. The results of Dr. Hooker's researches are published in the Memoirs of the Geological Survey, vol. ii. part 2, p. 431, in a paper entitled "On some Peculiarities in the Structure of Stigmaria."

‖ Subsequently Professor A. Ramsay (Local Director of the Geological Survey of Great Britain) and Mr. Warington Smyth (Mining Geologist to the Geological Survey of the United Kingdom) examined the *Stigmaria* beds in their official visits to the district.

of the district, considers that all the coal-beds in it are based on *Stigmaria* beds.*

In studying these beds care is needed in seeing that the rootlets of the *Stigmaria* really diverge from the main root, and permeate the bed in which they may be discovered, in the manner in which the roots of the water lily (as pointed out by Dr. Hooker) and those of many other aquatic plants permeate the silt beneath still waters. Portions of the main *Stigmaria* roots and even of the rootlets are to be found in the other beds, washed out of their soils (*Stigmaria* beds) and drifted like the stems of *Sigillaria* to which they belonged. From not distinguishing between the *mode of occurrence* of the *Stigmaria* and their rootlets in the different beds, the not unfrequent mistake has arisen of considering the remains of *Stigmaria* as so diffused throughout the various coal-measures that no conclusion can be drawn respecting their mode of growth in place.

In South Staffordshire, as in the other Coal-measure districts of Great Britain, the composition of the inorganic portions of the *Stigmaria* beds varies considerably, as, indeed, might be anticipated from its detrital mode of accumulation. At the same time the number of instances in which the mineral matter of these beds is of a character to afford good materials for fire-bricks, and is hence known as *fire-clay*, is somewhat remarkable. By reference to the Vertical Sections of the Geological Survey, Sheets 16, 17, and 18 (all relating to South Staffordshire), the numerous instances of fire-clays beneath the coal will be at once seen; and so far as my experience has extended the fire-clays so situated contain the *Stigmaria* roots, with every appearance of growth in place. At times it requires careful observation to detect the *Stigmaria* roots in the beds containing them, as well beneath the beds of coal, sufficiently important to have names assigned them, as beneath mere seams of an inch or two in thickness. As will be readily understood, even all traces of a coal above a *Stigmaria* bed may be absent, either from the carbonaceous matter having been removed by the stream or current of water which deposited new matter, such as sand, above it, or from the conditions not having been so far advanced as to permit the *Stigmaria* bed or soil to be coated over with such carbonaceous matter.†

Seeing the general occurrence of the *Stigmaria* beds beneath those of coal, a proper appreciation of them may become, as it has been already found in some districts, practically useful in tracing the outcrop of beds, especially where the crop of a coal itself may be uncertain, and the thickness of a *Stigmaria* bed may be considerable, though the latter necessarily, seeing the respective origin of the two, bears no relation to that of any coal which it may support, or be intermingled with.‡ When

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* Dawes, MSS.

† In some coal districts, as, for example, in South Wales, the carbonaceous matter, which formed the coal, has been sometimes entirely removed, and even channels cut in the supporting *Stigmaria* beds, by the water which bore, and allowed the deposit of, the sand or silt now forming sandstones or arenaceous shales, covering the eroded and non-eroded parts: such erosion having taken place when the coaly matter was unconsolidated.

An excellent example of the erosion of coal into channels, like those amid some peat bogs, occurs in the Forest of Dean, where it is known as "the Horse." This "Horse," with its tributaries, named "Lows," will be found well described by the late distinguished colliery viewer, Mr. John Buddle, in the Transactions of the Geological Society of London, new series, vol. vi. 213. The Memoir is accompanied by an illustrative plan and section.

‡ The intermingling of the *Stigmaria* and coal beds or seams has often led to the supposition, especially when a *Stigmaria* bed beneath any coal worked was rarely

"fire-clays" contain the *Stigmaria* roots, properly permeating their ancient soil, there is usually a little difficulty in practically tracing their crop, but when the mineral matter of these beds takes the more ordinary form of a sandstone or arenaceous shale, the case is different. Then an examination of the mode of occurrence of the *Stigmaria* roots themselves is essential, especially when the lithological character of the bed may be liable to change, and in some coal districts we have been enabled to trace the same *Stigmaria* bed from the ordinary condition of a fire-clay to a rock in which the arenaceous matter greatly prevailed.*

Note on the Mode of working the Coal and Ironstone of South Staffordshire. By Warington W. Smyth, M.A., Professor of Mining and Mineralogy to the Museum of Practical Geology.

A brief sketch of the modes of working the beds of coal and ironstone in South Staffordshire is appended, with a view of recording generally the practical methods, adopted at the present time, for the extraction of those rich stores of mineral wealth of which the geological relations have been described in the preceding pages.

The acknowledged requisite for the most advantageous method of working, viz. the combination of the cheapest mode of extracting the greatest possible quantity of mineral, with the safety and comfort of the men, has in this district been greatly modified by the circumstances of position, and an adherence to long established customs. In a few rare instances only have any attempts been made to substitute a new system for the old routine, and to such it will be needful to advert after we have viewed the principal features of the practice almost universally followed.

In the first place, the division of the ground into separate works is guided by the faults which in so many instances constitute natural boundaries and by the depth from the surface, of the deposits proposed to be worked; and an observer, conversant with districts of coal where extensive unbroken areas are worked at great depths by few shafts, cannot fail to be struck with the appearance of the South Staffordshire field, dotted over as it is with innumerable shafts, and deformed by the large waste heaps of slate and slack which so frequently surround them. The cause of this, lying in the subdivision into small areas, and the comparative shallowness of the workings, and conducive no doubt to simplicity in all the internal arrangements, afford such facilities for securing the desiderata above alluded to, that it must be a matter of surprise to find that certain ancient incomplete usages should so long have held their ground.

The shafts by which access to the coal and ironstone measures is to be obtained, are sunk two together, at a distance of six or eight yards asunder, and with a diameter of six or eight feet. Each shaft being

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touched or examined, that these beds occurred quite as much above coal beds as beneath them, the roof of a given working being formed of a *Stigmaria* bed. Illustrative instances of the interstratification of *Stigmaria* with coal beds in South Wales, will be found in the Memoirs of the Geological Society, vol. i. p. 153.

* The consolidation of *Stigmaria* beds is occasionally very considerable, even approaching that of quartz rock. Good examples of *Stigmaria* beds thus consolidated may be seen on the coast (at Lilliput) near Swansea, where from the infiltration of silica, two beds, each supporting small beds of coal, and penetrated by *Stigmaria* roots and rootlets in their relative places of growth, have become hard quartz rocks.

intended for a single rope or "band," is surmounted by a head-frame carrying one broad pulley of cast-iron, and the whimsey engine is so placed as to be able to serve two shafts at once, raising a loaded "skip" in the one, and lowering an empty one in the other, at the same time. The difficulties of sinking, as regards watery strata, being inconsiderable, except in some few cases, the ingenious and expensive application of wooden or iron tubbing, practised so frequently in the Belgian, and in our northern coal-fields, is almost unknown; and the shafts are lined with brick-work, unless when they pass through strata sufficiently strong to stand permanently without support. The area of the shafts is free from any obstruction, no "guides" being employed to regulate the passage of the "skips" or frames upon which the coal is piled in large masses surrounded by loose "rings," of sheet iron, and from which less than might be expected falls off during the ascent. Ponderous flat chains of three links, alternately short and long, with slips of wood inserted through the long links, are most frequently used for the drawing, and for shafts of moderate depth are very effective and safe.

Taken apart from minor details, the modes of working the mines are two in number, the first applied to the important beds called the "thick coal," and the "new mine;" and the second, termed "long work," (not, like the former, peculiar to the district,) employed in the other coal seams of from two to five feet in thickness, and in the ironstone measures.

The workings of the ten-yard coal are divided into compartments termed *sides of work*, which are separated from one another by "ribs," or walls of coal, from eight to ten yards thick, and of which no more are kept open at once than can be maintained in activity.

From the main roads, termed *gate-roads*, each *side of work*, unless commenced near the outer boundary, is accessible only through a narrow opening, cut, like the gate-road itself, in the lower part of the seam. "Stalls" are then driven out in the coal, each of them eight or ten yards wide, and are crossed again by similar galleries, leaving between them pillars of eight or ten yards square, but varied of course in dimension, according to local circumstances. For additional security during the working, small pillars of three or four yards square at the base, termed *men of war*, are spared out of the solid coal, wherever it is deemed necessary, to be rapidly prostrated and carried off, when the stall is fully opened. But the driving of the stalls themselves is a work involving no little waste of coal and insecurity to the colliers; the mass of coal of eight yards wide having to be undercut, or *holed* about a couple of yards in, a large amount of coal is cut up into slack by the "pike," or collier's pick, and the men are exposed to continual risk from falls of coal. As the various portions of the seam are successively "cut" at the side of the stall, and brought down, the colliers have to mount on heaps of slack or light wooden stages, and are necessarily exposed to still greater danger.

There is, in fact, perhaps scarcely any situation more suggestive of feelings of awe, than a side of work in the "thick seam," when a large fall of coal is brought down from the dusky heights of that lofty chamber; the thunder of the falling masses which seem to shake the solid earth and fill the air with a thick cloud of dust, contrasting fearfully with the dead silence which ensues, and which the hardy colliers scarce break by a whisper, whilst in suspense they listen for the slightest crack which might portend a farther fall.

When a compartment has thus been cleared and the large pillars sometimes a little thinned, the "slack" or small coal and dust is left in

heaps, and to guard againt the spontaneous combustion, apt to ensue from the decomposition of small particles of pyrites, a dam is placed in the "bolt hole," and this portion cut off from all communication with the rest of the workings.

The second mode of getting, by what is called long work, need not be described at length, being very similar to that practised in Shropshire, Derbyshire, and other districts; it is, as elsewhere, variable according to the condition of the roof, &c., the road-ways being sometimes driven out through the "whole coal," which is then worked back towards the shafts, in other cases the roads being maintained through the "gob" or waste from which the coal has been removed, as the extraction proceeds from the shafts towards the limits of the field.

Very important, however, in an economical point of view, both to the lord of the soil, and to the lessee, as well as to the interest of humanity, is the success which has attended the efforts of certain coalowners to get the ten-yard coal on the principles of "long work," as exemplified in the pits of the Messrs. Foster, of Mr. Gibbons, and at Congreaves. We have seen that by the usual method, what with the ribs and pillars left untouched and the quantity of coal cut up into slack, a vast amount of useful fuel—of what in fact in a very few years *must* become of much higher value, is utterly lost to the nation.

It is not too much to assert, that from one-third to one-half of the coal is thus left useless, (some little only of the ribs and pillars being afterwards recoverable in a damaged condition,) an amount of squandered natural advantages almost without a parallel.

By the common plan it is considered that 16,000 tons of coal obtained from an acre of ground represents a very fair produce, and no doubt a very much lower number is often obtained. At Messrs. Foster's, the coal is worked in two divisions, the upper half first, by long work, and then some months afterwards, when the "shut" or roof has fully subsided, the lower half is worked by the same method, and a total amount of from 26,000 to 31,000 tons of coal to the acre is procurable, and it need only be added to the conclusions suggested by a comparison of these numbers, that, under this newly applied system, there has been enjoyed a comparative immunity from those frequent and frightful accidents which have gained the workings of the Thick coal a most unenviable notoriety.

In conclusion, the ventilation of these works requires a short notice, from the fact, that although the coal is not highly charged with fire-damp, very serious accidents have happened from explosions, and the every-day state of some of the pits cannot be regarded without dread. The establishment of a current of air is left much to accident; and the causes disposing the air to travel down one shaft and up the other are so easily disturbed by a change of wind, or other trivial cause, that a stagnation is frequently produced, or the pits are said to *fight*, and during the contest, if nothing more serious occurs, the colliers are obliged to "play" or absent themselves.

"Air-heads," of not more than 9 or 10 feet sectional area, are driven in the coal parallel with the gate-roads, and communicate with the "sides of work;" but unless, according to the suggestion of Ryan, they are driven in the upper part of the seam, there must frequently accumulate in those high working stalls a magazine of explosive gas ready to fire on the first opportunity, so easily afforded by a fall of coal, a change in the barometer, or the imprudence of a workman.

It need scarcely be observed how greatly the danger is augmented, when the "air heads" are not brought up simultaneously with the main workings, yet under the "butty" or "chartermaster" system, it is too

common to find those important works omitted for long distances, and the men working in a confined space charged with foul gases and fire-damp almost to the explosive point.

A great deal might be said on the details of this and the previous subjects, but I would hope that these short notes may only serve as a record of rude practices soon to be improved, and must refer the reader, desirous of further information on these heads, to the evidence before the Committee of the House of Commons in 1835, of the House of Lords in 1849, to the report of Mr. J. Kenyon Blackwell, to Smith's Miner's Guide, published in 1836, and to Mr. Gibbons's pamphlet on his method of ventilation. No one, I believe, even practically unacquainted with the subject, will rise from the perusal of those statements without feeling that in the waste of a treasure of unique richness, and in the abandonment of an energetic and honest class of workmen to the dangers resulting from the absence of mental training, we have hitherto deserved as a nation but little credit for the stewardship of some of our finest coal-fields.

NOTE.

The following extracts from Plot's Natural History of Staffordshire, published in 1686, may serve to show the state of the South Staffordshire district, as regarded its coal and iron at that time. Speaking of the common coal then raised at Wednesbury, Dudley, and Sedgley, Dr. Plot says, "of which sort there is so great plenty in all "parts of the country, (especially about the three above mentioned places,) that most "commonly there are 12 or 14 *colery's* in work, and twice as many out of work, "within 10 miles round. some of which afford 2,000 tuns of coal yearly, others three, "four, or five thousand tuns. The upper or topmost beds above the ironstone lying "sometimes ten, eleven, or twelve yards thick. * * * * * Nor indeed "could the country well subsist without such vast supplies, the wood being most of it "spent upon the ironworks."

Alluding to the attempts which were made to smelt iron with coal or coke, he says, "The last effort that was made in this country for making iron with pit coal, was also "with raw coal, by one *Mr. Blewstone*, a high *German*, who built his furnace at "Wednesbury, so ingeniously contrived that only the flame of the *coal* should come to "the *oare*, with several other conveniences, that many were of opinion he would "succeed in it. But experience, that great baffler of speculation, showed it would not "be. The sulphureous vitriolic steams that issue from the pyrites, which frequently, "if not always, accompanies *pit coal*, ascending with the flame, and poysoning the *ore* "sufficiently to make it render much worse *iron*, than that made with *char-coal*, though "not perhaps so much worse, as the body of *coal* it-self would possibly doe."

The different kinds of iron made are mentioned under the heads of 1. Redshare; 2. Coldshare; 3. Blend metell; and tough iron, the last being the best, and chiefly made from ores obtained at Rushall. The ores were first calcined on the open ground, "with small charcoal, wood, or sea-cole." After this they were taken to the blast furnace, where they were smelted with charcoal, one basket of the latter being used to one basket of calcined ore. The iron run from the furnaces was then taken to the forges, which were of two kinds, one known as the Finery, the other as the Chafery, and made into bars. For cutting the iron into rods it was taken to Slitting mills, and there cut and rolled.

Speaking of the improvement then made in iron smelting, Dr. Plot remarks, "we "shall find it very great, if we look back upon the *methods* of our *ancestors*, who made "*iron* in *foot blasts*, or *bloomeries*, by mens treading the bellows, by which way they "they could make but one little lump or *bloom* of *iron* in a day, not 100 weight, leaving "as much *iron* in the *slag* as they get out. Whereas now they will make two or three "tuns of *cast iron* in 24 hours; leaving the *slag* so poore, that the founders cannot "melt them again to profit. Not to mention the vast advantage they have from the "new invention of *slitting mills*, for cutting these barrs into rodds, above what they "had antiently."

It would appear that the first successful smelting of iron ore by means of coal, then usually called pit or sea coal, was effected by Dud Dudley in the year 1619. Other unsuccessful attempts by Simon Sturtevant, John Rovenson, and others having been previously made.

Dud Dudley in his book Metallum Martis, 1665, says, that having been taken from Baliol College, Oxford, where he was then a student, in 1619, "to look and manage "3 iron works of my fathers, 1 furnace, and 2 forges, in the Chase of Pensnet, in "Worcester-shire, but Wood and Charcole, growing then scant, and Pit-coles in "great quantities abounding near the furnace, did induce me to alter my furnace, and "to attempt by my new invention, the making of iron with pit-cole, assuring myself "in my invention, the loss to me could not be greater then others, not so great, "although my success should prove fruitless; but I found such success at first tryal "animated me, for at my tryal or blast I made iron to profit with pit-cole, and found "*Facere est addere Inventioni.*" * * *

"After I had made a second blast and tryal the fesibility of making iron with pit-"cole and sea-cole I found by my new invention, the quality to be good and profitable, "but the quantity did not exceed above 3 tuns per week."

A patent for smelting iron ore by pit or sea coal was granted to Dud Dudley in 1619. In the year following his works were swept away by a great flood, known for long afterwards as the May-day flood.

We, however, find Dud Dudley stating that the works were repaired, and that he "made annually great store of iron, good and merchantable, and sold it to divers men, "yet living (1665) at twelve pounds per tun." Making "all sorts of cast iron wares, as "brewing-cysterns, pots, morters, and better and cheaper than any yet were made "in these nations with charcoles." Subsequently we find him smelting with pit-cole at Himley Furnace, Staffordshire, having been "ooted of his works and inventions "before-mentioned by the ironmasters and others wrongfully," and again at Hasco-Bridge in the parish of Sedgley, Staffordshire, making seven tons of iron per week—"the greatest quantity of pit-cole iron that ever yet was made in Great Britain.

Dud Dudley's works were riotously destroyed, and he himself by adhering to the royal cause became utterly ruined.

As respects the prices of the iron made by Dud Dudley, he states that "he did sell "pig or cast iron made with pit-cole at four pounds per tun, many tuns, in the twentieth "year of King James with good profit." He further says—"The author did sell bar "iron good and merchantable, at twelve pounds per tun and under, but since bar "iron hath been sold for the most part ever since at 15*l.*, 16*l.*, 17*l.* and 18*l.* per tun by "charcoal iron masters."—*Metallum Martis*, p. 32.

NOTE on the COAL RAISED and IRON MADE in 1858 in SOUTH STAFFORDSHIRE. By ROBERT HUNT, F.R.S., Keeper of Mining Records.

The quantity of Coal raised in South Staffordshire was 4,995,780 tons; the present value of which may be regarded as 1,248,945*l.* sterling.

The quantity of coal required for calcining and for smelting the iron ore is at the rate of about three tons of coal for one ton of iron, or about 1,793,427 tons were employed in 1858 for that purpose. This is exclusive of the coal required for the manufacture of bar iron, &c.

The quantity of ironstone raised from the South Staffordshire coal measures, was about 959,000 tons; the average production of iron from this ironstone ore being about 33 per cent.

In addition to this ore, the following and some other ironstones were consumed in South Staffordshire:—

	Tons.
From North Staffordshire:—	
Sent by railway, iron ore, *calcined* - - -	76,367
„ „ „ „ uncalcined - -	15,797
Sent by canal „ „ *calcined* - - -	135,861
„ „ „ „ uncalcined - -	79,327
From Lancashire and Cumberland, about - -	30,000
„ Forest of Dean, about - - - -	13,000
„ Northamptonshire and other places, about - -	50,000
	400,352

The quantity of pig iron made in South Staffordshire for the last three years has been as follows :—

1856.	1857.	1858.
Tons.	Tons.	Tons.
777,171	657,295	597,809

The number of furnaces built and in blast is given in the first table ; the number of mills and forges in the second.

The Number of Iron Furnaces in Blast in South Staffordshire and Worcestershire, 147.

No.	Names of Works.	Owners.	Furnaces built.	Furnaces in blast.	Furnaces in blast in District.
1	Bentley Heath - -	Riley and Co. - -	3	0	
2	Birchills, New, *Walsall* -	Henry Smith - -	5*	3	
3	„ Old „ -	F. C. Perry - -	2	2	
4	Bloxwich, Green Lanes, *Walsall.*	T. and C. Highway -	2	2	
5	Bovereux, *Bilston* -	Wm. Baldwin and Co. -	2	1	
6	Brettell Lane „ -	Hall, Holcroft, and Pearson	2	2	
7	Broadwaters „ -	S. Groucutt and Sons -	3	3	
8	Brook „ -	G. H. and A. Hickman -	3	2	
9	Caponfield „ -	John Bagnall and Sons -	3	3	
10	Chillington - -	Chillington Iron Company	4†	3	
11	Coneygree, *Tipton* -	Lord Ward - -	3	2	
12	Corbyns Hall, - *Dudley*	Wm. Matthews and Co. -	4	3	
13	„ „ New „ -	B. Gibbons - -	4	2	
14	Coseley, *Bilston* - -	Jos. and Thomas Turley -	2	2	
15	Crook Hay - -	Geo. Thompson and Co. -	4	2	
16	Darlaston Green - -	Samuel Mills - -	3	3	
17	Deepfields, *Bilston* -	Benton and Pemberton -	3	1	
18	Dixon's Green, *Dudley* -	W. Haden - -	1	1	
19	Dudley Port - -	Hopkins and Son - -	2	2	
20	Dudley Wood - -	New British Iron Co. -	4	4	
21	Ettingshall, *Bilston* -	T. Banks and Son -	2	1	
22	Gold Hill, *West Bromwich*	John Bagnall and Sons -	3	3	
23	Hallfields - -	B. Gibbon, jun. - -	1	1	
24	Hatherton - -	Highway, Brothers -	2	2	
25	Herbert's Park, *Bilston* -	David Jones - -	1	1	
26	Horseley, *Tipton* - -	Colburn and Sons - -	4	3	
27	Ketley's, *Dudley* - -	B. Gibbons - -	3	3	
28	Lays, *Stourbridge* -	W. and G. Firmstone -	3	3	
29	Level, New, *Brierley Hill*	Lord Ward - -	3	3	
30	„ Old „ -	Hall, Holcroft, and Pearson	2	1	
31	Millfield, *Bilston* - -	B. Gibbon, jun., and Co. -	3	3	
32	Moseley Hall, *Wolverhampton.*	Chillington Company -	3	3	
33	Netherton - -	N. Hingley and Sons -	2	2	
34	„ - - -	M. and W. Grazebrook -	2‡	2	
	Carried forward -	- - - -	93	74	

* 4 furnaces were in blast for a short time. The average of the year was 3 furnaces.

† During a portion of the year the Chillington Company had 4 furnaces in blast.

‡ These furnaces are entirely cold blast.

Number of Iron Furnaces in Blast, &c.—*continued.*

No.	Names of Works.	Owners.	Furnaces built.	Furnaces in blast.	Furnaces in blast in District.
	Brought forward -	- - - -	93	74	
35	New Furnaces, *Bilston* -	S. H. Blackwell and Co. -	5	4	
36	Oak Farm, *Dudley* -	Oakfarm Furnace Company	2	2	
37	Oldbury - - -	William Bennit - -	4	4	
38	Old Hill, *Dudley* -	T. and J. Badger - -	2	1	
39	Old Park - -	Lloyds, Foster, and Co. -	3	3	
40	Osier Bed - -	W. H. Sparrow and Co. -	3	3	
41	Park Head - -	Evers and Martin - -	2	2	
42	Parkfield - -	Parkfield Iron Company* -	5	4	
43	Park Lane, *Tipton* -	Thomas Morris - -	2	1	
44	Pelsall - - -	Davies and Bloomer -	2	2	
45	Priestfield - -	W. M. Ward and Sons -	3	3	
46	Priors Field - -	H. B. Whitehouse - -	3†	3	
47	Rough Hay, *Darlaston* -	Addenbroke, Smith, and Pidcock.	2	2	
48	Russell's Hall, *Dudley* -	S. H. Blackwell and Co. -	5	4¾	
49	Shut End, *Stourbridge* -	John Bradley and Co. -	4	3	
50	Spring Vale, *Bilston* -	Jones and Murcott -	3	2¼	
51	Stone Field - -	G. H. and A. Hickman -	1	1	
52	Stour Valley - -	B. Richards - -	2	0	
53	Stow Heath - -	W. H. Sparrow and Co. -	5	4	
54	Tipton - - -	E. Creswell and Sons -	2	2	
55	Tipton Green - -	Gibbons and Robert -	4	4	
56	Toll End, *Tipton* -	Toll End Company -	2	0	
57	Union - - -	Phillip Williams and Company.	3	3	
58	Wednesbury Oak -	Ditto - - -	3	2	
59	Willinghall - -	Fletcher, Solly, and Urwick	3	2	
60	Wellingsworth - -	Haines and Company -	3	3	
61	Windmill End - -	Woodall and Smith -	3	2	
62	Withymoor - -	W. Dawes - -	2	2	
63	Wolverhampton - -	Edward Poole and Co. -	3	2	
64	Woodside - -	Cochrane and Company -	3	2	
		Total - -	182	147	

Mills and Forges in South Staffordshire District, with the Number of Puddling Furnaces.

1	Jno. Bradley and Co. -	Stourbridge Works	Stourbridge -	23	
2	Ditto - - -	Brierley Works -	Kingswinford -	38	
3	Ditto - - -	Shut End - -	Ditto - -	34 =	95
4	Jno. Bagnall and Sons -	Imperial Works -	Wednesbury -	26	
5	Ditto - - -	Lee Brook - -	Ditto - -	28	
6	Ditto - - -	Gold's Hill - -	Tipton - -	31 =	85
7	G. B. Thorneycroft and Co.	Shrubbery Works	Wolverhampton	40	
8	Ditto - - -	Swan Garden -	Ditto - -	30 =	70
9	Barrows and Hall - -	Bloomfield Works	Tipton - -	56	
10	Ditto - - -	Factory Works -	Ditto - -	22	
11	Ditto - - -	Tipton Green -	Ditto - -	11 =	89
12	Chillington Iron Company	Chillington Works	Wolverhampton	56	
	Carried forward -	- - - -	- - -		339

* 3 furnaces in blast for 3 months, and 4 for 9 months.
† 2 only in blast one half the year.

Mills and Forges in South Staffordshire, &c.—*continued.*

	Brought forward -	- - - -	- - -		339
13	Chillington Iron Company	Lee Brook - -	Wednesbury -	23	
14	Ditto - - -	Bradley - -	Bilston - -	14	
15	Ditto - - -	Capponfield - -	Ditto - -	16	=109
16	Walter Williams - -	Albion Works -	West Bromwich	50	
17	Ditto - - -	Great Bridge -	Tipton - -	12	= 62
18	British Iron Company -	Corngreaves -	Dudley - -	56	
19	Ditto - - -	Brierley Hill -	Ditto - -	18	= 74
20	Jones and Murcott -	Spring Vale - -	Bilston - -		68
21	John Dawes and Son -	Bromford Works -	Oldbury - -		51
22	W. and J. Sparrow and Co.	Osier Bed - -	Wolverhampton	26	
23	Ditto - - -	Bilston Works -	Bilston - -	32	= 58
24	Phillip Williams and Sons	Wednesbury Oak -	Tipton - -		32
25	J. Walker and Co. -	Patent Shaft Company.	Wednesbury -		48
26	Lord Ward - -	Round Oak - -	Brierley Hills -		45
27	Corbyn's Hall Iron Company	Corbyn's Hall Works.	Kingswinford -		40
28	Solly Brothers - -	Lee Brook - -	Wednesbury -	25	
29	Ditto - - -	Great Bridge -	Ditto - -	18	= 43
30	W. Riley and Son - -	Highfield Works -	Bilston - -		26
31	Rose, Higgins, and Rose -	Bradley Works -	Ditto - -		33
32	Browning and Jackson -	Deepfields Works -	Ditto - -		10
33	Brown and Frere - -	The Lays - -	Dudley - -	28	
34	Ditto - - -	The New Lays -	Ditto - -	10	= 38
35	J. and E. Walker - -	Old Church and Gospel Oak.	Tipton - -		27
36	Atlas Iron Company -	Atlas Works -	West Bromwich		13
37	Sir S. Glyn, Bart. - -	Oak Farm - -	Kingswinford -		38
38	R. Jeffries - -	Hart's Hill Works	Brierley Hill -		30
39	E. Cresswell and Sons -	Tipton Works -	Tipton - -	20	
40	Ditto - - -	Moxley Works -	Wednesbury -	10	= 30
41	Thomas Wells - -	Moxley - -	Ditto - -		25
42	Hickman and Co. - -	Groveland Works -	Tipton - -	18	
43	Ditto - - -	Stonefield - -	Bilston - -	10	= 28
44	Davis and Bloomer -	Pelsall Works -	Walsall - -	12	
45	Ditto - - -	Gold's Hill - -	Tipton - -	11	
46	Ditto - - -	Greet's Green -	West Bromwich	20	= 43
47	David Jones - -	Herbert's Park -	Darlaston - -	15	
48	Ditto - - -	Bilston Brook -	Bilston - -	8	= 23
49	Plant and Fisher - -	Dudley Port Works	Tipton - -		20
50	E. Page and Sons - -	Roway Works -	West Bromwich		23
51	S. Mills - - -	The Green Ironworks.	Darlaston - -		22
52	Lee and Bolton - -	The Hyde Works -	Stourbridge -		21
53	S. Groucutt and Sons -	Bankfield Works -	Bilston - -		20
54	Fletcher, Rose, and Co. -	Albert Works -	Moxley - -		21
55	Daniel Rose - -	Bull's Bridge -	Ditto - -		10
56	Wm. Rose - -	Batman's Hill -	Bilston - -		10
57	Wright and North -	Monmore Green -	Wolverhampton		11
58	Isaac Jenks - -	Minerva Works -	Ditto - -		13
59	Hall, Holcroft, and Pearson	The Level -	Brierley Hill -		17
60	Budd and Co. - -	Tividale Ironworks	Tipton - -	9	
61	Ditto - - -	Brockmoor Works	Dudley - -	6	15
62	Thomas Silvester and Son	Spon Lane - -	West Bromwich		12
63	Beasley and Farmer -	District Forge -	Smethwick -		20
64	Millington and Co. -	Summer Hill -	Tipton - -		15
65	F. Giles and Co. - -	Dudley Port Works	Ditto - -		14
66	Badger and Co. - -	Ditto - -	Ditto - -		14
67	Evers and Sons - -	Cradley Works -	Dudley - -		17
68	N. Hingley and Sons -	Netherton Works -	Ditto - -		15
69	John Wheeley and Co. -	Brettel Lane - -	Stourbridge -		16
70	Corkley Iron Company -	Corkley - -	Kidderminster -		12
	Carried forward -	- - - - -	- - -		1,671

Mills and Forges in South Staffordshire, &c.—*continued.*

	Brought forward -	- - - -	- - -	1,671
71	Lloyds, Foster and Co. -	Old Park - -	Wednesbury -	12
72	Ditto - - -	King's Hill - -	Ditto - -	6 = 18
73	Deaken and Dodd -	Monmer Lane Iron-works.	Willenhall -	11
74	Eagle Coal and Iron Company.	Greet's Green -	West Bromwich	14
75	J. Whitehouse - -	Ridge Acre - -	Ditto - -	19
76	Crange and Holden -	Great Bridge -	Ditto - -	10
77	John Stones and Son -	The Grove - -	Smethwick -	10
78	Granager and Powers -	- - - -	Ditto - -	10
79	Keep and Watkin - -	Swin Works -	Stourbridge -	13
80	Geo. Thompson and Co. -	Crook Hay Works	West Bromwich	18
81	Gilpin and Sons - -	Wedge's Mills -	Walsall - -	6
82	J. Marshall - -	Monway Works -	Wednesbury -	6
83	Johnson and Co. - -	Church Lane -	West Bromwich	7
84	Bissell, Kay, and Bissell -	Hill Top - -	Ditto - -	10
85	Hipkins and Co. - -	Great Bridge -	Ditto - -	5
86	J. Gregory - -	Spon Lane - -	Ditto - -	6
87	Hartland and Co. - -	Smethwick - -	Ditto - -	8
88	Wm. Marshall - -	- - - -	Ditto - -	3
89	J. Hodgetts - -	- - - -	Ditto - -	3
90	Wm. Morris - -	- - - -	Tipton - -	4
91	J. Haines and Co. - -	Sheep Wash - -	Ditto - -	10
92	Hunt and Sons - -	Brade's Works -	Oldbury - -	8
93	E. B. Whitehead - -	- - - -	Tipton - -	9
94	Wm. Baldwin and Co. -	Bovereux Works -	Bilston - -	6
95	Wm. Banks - -	Ettingshall Works	Ditto - -	11
96	Thompson and Burford -	Bradley Hall Works	Ditto - -	10
97	Hampton and Brereton -	Pot House Bridge Works.	Ditto - -	7
98	Baldwin and Co. - -	Horseley Fields Works.	Wolverhampton	3
99	Whittington Company -	Whittington Works	Stourbridge -	7
100	Banks and Morgan -	Broadwaters - -	Kidderminster -	5
101	Baldwin Brothers -	Wildon Works -	Ditto - -	5
102	Edmund Page - -	- - - -	Smethwick -	12
	Total - -	- - - -	- - -	1,945

The number of collieries enumerated in the Mineral Statistics for 1858 is 415 in this coal-field. Each of these collieries will have at least two shafts, and many of them more.

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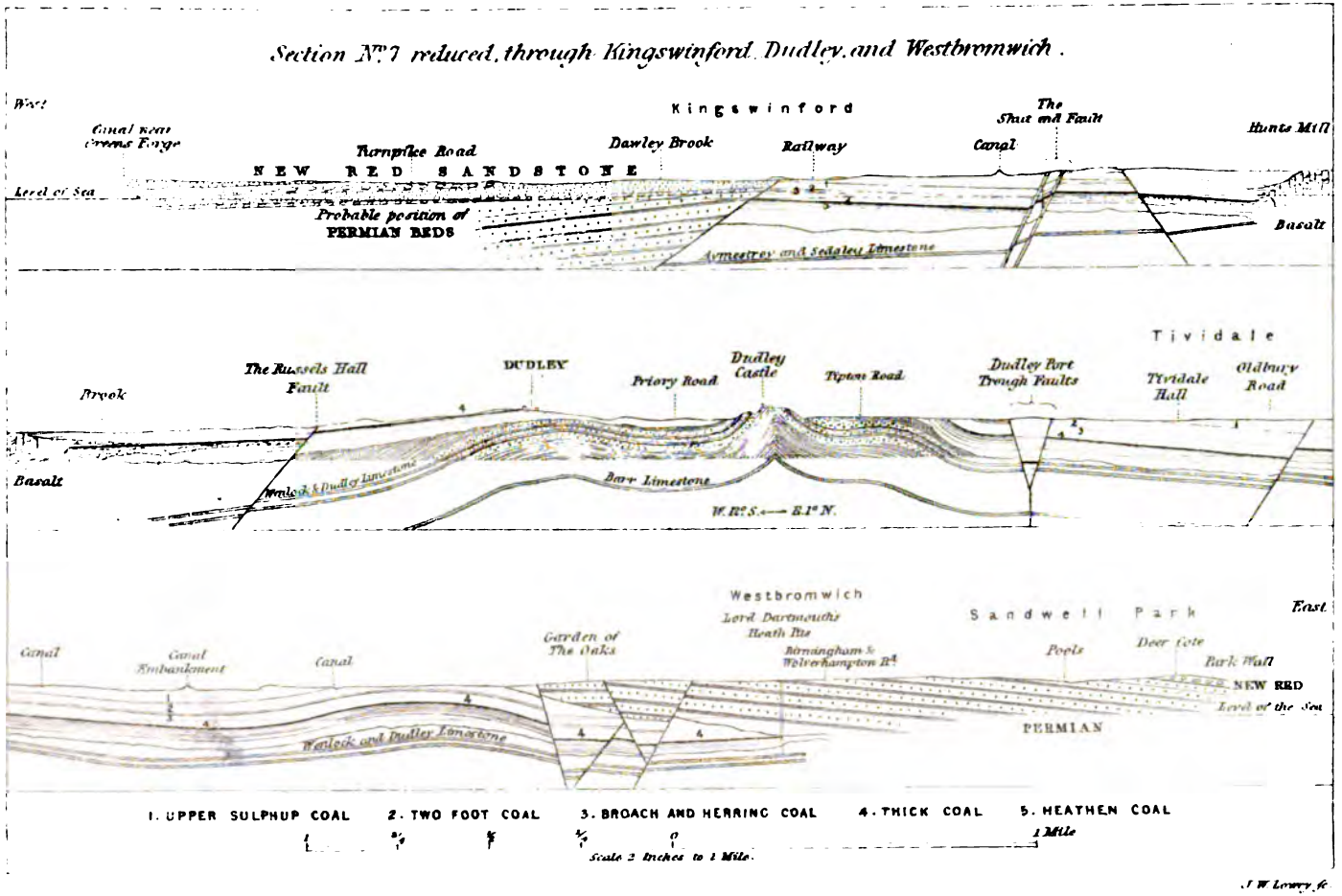
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The Shut and Fault
Hunts Mill
Canal near Cross Forge
Turnpike Road
Dawley Brook
Railway
Canal
NEW RED SANDSTONE
Level of Sea
Probable position of PERMIAN BEDS
Basalt
Aymestrey and Sedgley Limestone
Tividale
The Russels Hall Fault
DUDLEY
Priory Road
Dudley Castle
Tipton Road
Dudley Port Trough Faults
Tividale Hall
Oldbury Road
Brook
Basalt
Wenlock & Dudley Limestone
Barr Limestone
W. R.ts S.— E.t.s N.
Westbromwich
Lord Dartmouth's Heath Pits
Sandwell Park
East
Canal
Canal Embankment
Canal
Garden of The Oaks
Birmingham & Wolverhampton R.y
Pools
Deer Gate
Park Wall
NEW RED
Level of the Sea
Wenlock and Dudley Limestone
PERMIAN
1. UPPER SULPHUP COAL
2. TWO FOOT COAL
3. BROACH AND HERRING COAL
4. THICK COAL
5. HEATHEN COAL
1 Mile
Scale 2 Inches to 1 Mile.
J. W. Lowry fc.

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RECORDS

OF THE

SCHOOL OF MINES

AND OF

SCIENCE APPLIED TO THE ARTS.

VOL. I. PART III.

MEMORANDUM.

In each Table of the imports of Copper and re-exports, pp. 419, 428, 439, 450, 464, *and* 478, *the word* "MANUFACTURES" *should be placed above the word* "VALUE" *in the last column.*

ERRATUM.

Page 419. *For £ s. d. under Total in the last line read* Tons. cwts. qrs.

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PRINTED FOR HER MAJESTY'S STATIONERY OFFICE.
PUBLISHED BY
LONGMAN, BROWN, GREEN, AND LONGMANS.

1853.

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VOL. I. PART III.

ON THE MINES OF WICKLOW AND WEXFORD.

BY

WARINGTON W. SMYTH, M.A., CAMB.,

MINING GEOLOGIST TO THE GEOLOGICAL SURVEY OF THE UNITED KINGDOM.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF
HER MAJESTY'S TREASURY.

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE.
PUBLISHED BY
LONGMAN, BROWN, GREEN, AND LONGMANS.

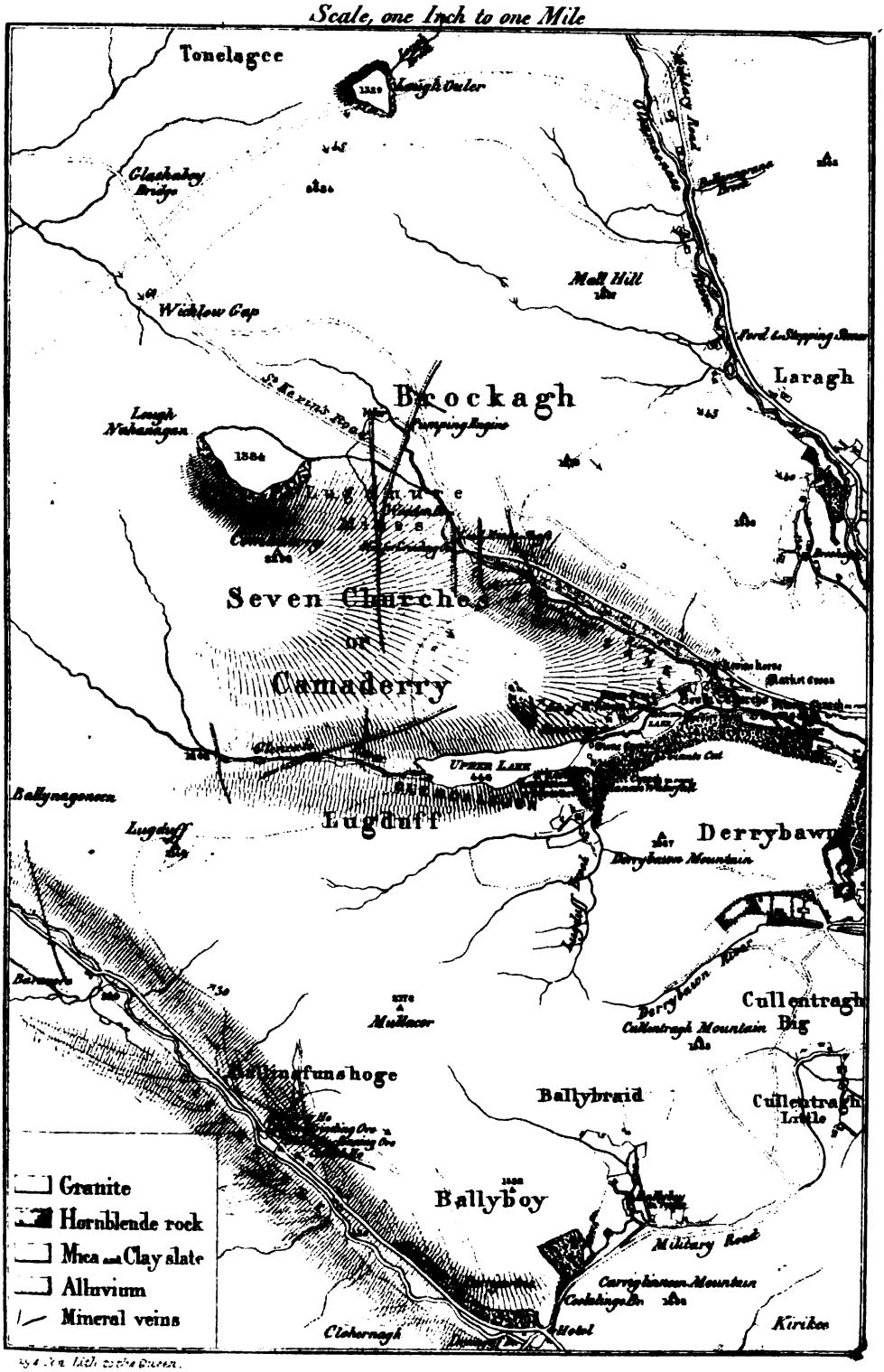
1853.

LONDON: PRINTED BY GEORGE E. EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.

MAP OF THE MINING DISTRICT OF

LUGANURE GLENDALOUGH AND GLENMALURE

Scale, one Inch to one Mile

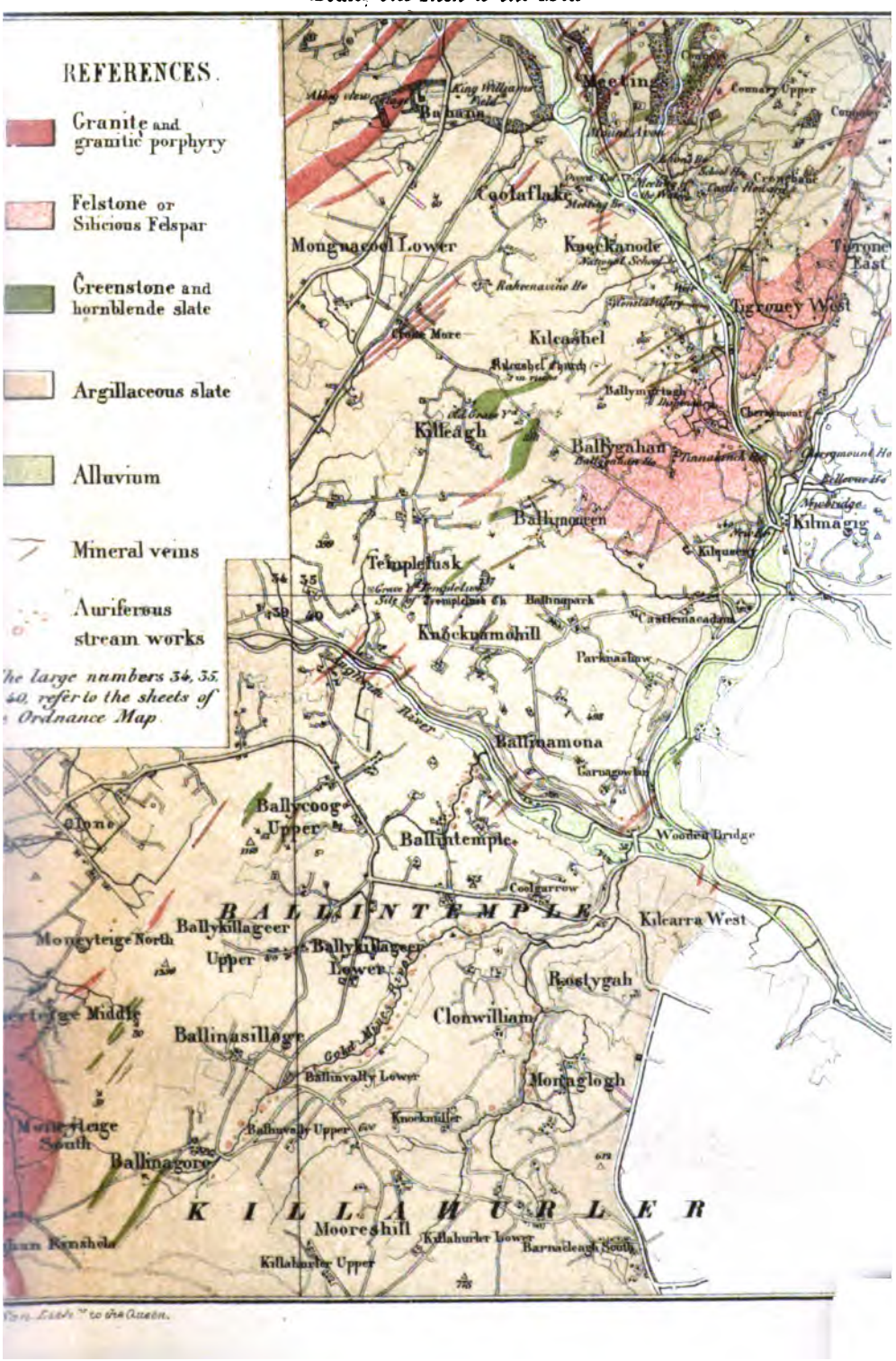


MAP OF THE MINING DISTRICT

extending

FROM CROGHAN KINSHELA TO CONNARY

Scale one Inch to one Mile



On the Mines of Wicklow and Wexford.

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MINING GEOLOGIST TO THE GEOLOGICAL SURVEY OF THE UNITED KINGDOM.

THE county of Wicklow has long enjoyed a celebrity due no less to its mines and minerals than to the natural beauties which adorn its landscapes: the copper ores of the Vale of Ovoca attracted attention at a very early period, and the gold which was discovered towards the close of the last century, excited great interest among all classes on both sides of the Channel. At the present day the mineral produce of the county may in some respects be less abundant than heretofore, but in others it has been much increased; and independently of the intrinsic value of the substances thus realized, the constant employment of a very large number of the working classes invests the subject with great importance.

The mines of Wicklow and the adjacent counties were very fully described by Mr. Weaver in his excellent Memoir on the Geological Relations of the East of Ireland, read before the Geological Society of London, in May 1818. Many of the features of Geological Science have been modified since that time, and its economic applications have passed through various phases, which render it desirable to offer a view of the present condition of the district; yet Mr. Weaver's paper remains an instructive example of the advantages to be derived from the publication at various intervals of detailed descriptions of mining localities, advantages which must be appreciated by all those who are personally interested in mining operations, and cannot but be valuable to the higher aims of science pursued for its own sake.

The natural division of the county of Wicklow into two parts,—an elevated mountain tract of granite on the west, and a region mostly composed of clay-slate on the east,—coupled with the distinct character of the metalliferous deposits respectively occurring in these portions, lead to the consideration of our subject under the following heads, 1st, the lodes or mineral veins in the granite; 2dly, the ore deposits in the clay-slate; and

3dly, the gold and other minerals which have been met with in the drift or superficial detritus.

The boundary line between the granitic and slate regions runs from N.N.E. to S.S.W.; and within a small width along its western side veins of lead ore have been discovered at intervals, for a distance of about 30 miles, if we include also a few miles which lie within the county of Dublin. The generally received view of the eruptive origin of this granite, and the effect which its original high temperature has produced on the clay-slate in contact with it, will be discussed elsewhere; and it is only necessary to observe, that although the modifying action has been so intense that a band of these slates for about half a mile in width, all along the edge of the granite, has been metamorphosed into mica slate, and the crystallisation of numerous anhydrous silicates has been developed, there is no ascertained instance of a metalliferous vein occurring altogether within the limits of the slate near this junction; and in almost every case where a few have been traced towards the overlying beds of that rock, they disappear as they approach it.

The granite of this district is generally of a grey tint and coarse structure; of its component parts the quartz is colourless, the felspar nearly always white, and the mica very commonly black. Accidental minerals rarely enter into its constitution, but it is to be observed, as a point of some importance, that in the neighbourhood of the metalliferous veins, a green steatitic mineral in small irregular flakes and lumps occurs abundantly, and not unfrequently occasions a softness and tendency to disintegration through the whole mass. In some portions of the tract large crystals of felspar make their appearance, rendering the granite porphyritic, and lending it very much the aspect of the granites of Cornwall.

The surface of the mountainous region is so covered with bog that the fundamental rock can rarely be seen, except in the brook courses and on the hill-tops, where the vegetable covering has been swept away by the rains. It may possibly be a result of this concealment of all the central granite, that lodes have seldom been observed at a greater distance than a mile and a half from the edge of the slate rocks, near which line of boundary most of the denuded places are situated. At such spots, however, it is remarkable that the principal mass is seamed by a

vast number of veins of a granitic character, some of a finer others of a coarser grain than the adjacent rock, and in their origin partly contemporaneous with its solidification and partly of a more recent date, These veins frequently contain other minerals, as steatite, garnets crystallized as well in the icosite-trahedron as in the rhombic dodecahedron, sparry iron, and, more rarely, beryll; and from their intimate relation to the mineral veins deserve a close attention.

The granitic veins, varying from an inch to several feet in width, are not very uniform in their direction, but exhibit a general tendency to follow very nearly the meridian line, a course analogous to that of the prevailing joints of the great rock masses. A riband of quartz frequently accompanies them, sometimes at the side, and sometimes in the middle of the vein, and evidently formed by simultaneous action on both sides of a narrow crack, which, when rather wider than usual, has allowed the development of quartz crystals with their points facing each other. Dislocations of some of the veins may be observed, but the contradictory phenomena offered by them would appear to indicate that at the time of the deposition of the longitudinal quartz strings, the granite of the veins must have been in a yielding condition. Thus in Fig. 1. of the accompanying examples, taken from Glendalough, the quartz-thread has been twice shifted by cross fissures, which have not altered the position of the granite vein. In Fig. 2. a vein of compact quartz has cut through both the varieties of granite, and has itself been divided and shifted by the narrow threads of crystallized quartz.

Fig. 1.

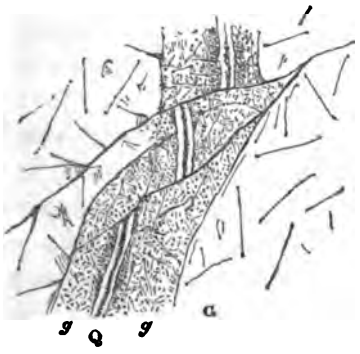
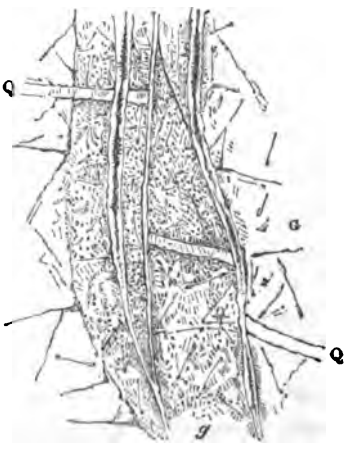


Fig. 2.



G Granite.
g vein-granite, often containing steatite.
Q Quartz veins.

In almost every instance which has fallen under my notice, each metalliferous vein consists, on the hanging or upper side, of a rib of granitic material,—a true granite vein indeed, generally coarse-grained and white, but sometimes assuming a beautiful pink tint from the predominance of felspar of that colour. Mica, often in large laminæ, is an abundant ingredient, and is commonly the white species known as potash mica, whilst that of the adjacent granite is often the black or soda mica in more distinct crystalline plates.

To whatever origin we may refer the great mass of enveloping granite, it is difficult to assign to these veins any other mode of formation than that to which we may ascribe the deposition of the various substances which occur in the mineral lodes, with which the granite veins are so closely associated. The minerals most frequently appearing in the lodes are galena, zincblende, carbonate of iron, copper pyrites, quartz, barytes, and calcareous spar, all of which, we have reason to believe, have been deposited from solution; and in extending this view to the granite veins, the felspar and mica alone present the difficulty of not occurring mingled with the ore-bearing parts of the lode. The first impression produced on the observer at many localities by the friable character of the granite veins is, that they have been mechanically made up from the detritus of the adjoining granite; but an examination of other spots will, I think, lead to the conviction that the constituent parts have been chemically placed where we now find them.

The felspar and mica are sometimes found in crystalline forms, the development of which has not been impeded by the quartz, a fact, however, not more remarkable in these veins than in granite rocks generally. The position of the granitic veins on the hanging side of the entire fissure, (as represented in several of the following diagrams,) seems to show that they fill a part of the lode which was rent open after the consolidation of the minerals on the lower or "foot-wall" side; and I shall have to point out one instance in which I observed a vein cutting obliquely through all the rest, filled almost solely with white mica, and which being but from 1 to 3 inches in width, can have been filled with that mineral only by crystallization from a watery solution.*

* The most satisfactory proof that mica frequently crystallizes from watery solutions is obtained from the fact, that it often occupies the shape

Mines of the Granite District.—The most important groups of lodes, or mineral veins, occur in Glendasane and Glenmalure, two valleys which open in straight lines with a N.W. and S.E. course, or nearly perpendicular to the general strike of the mountain range, and, from their bold and abrupt character, form a very remarkable physical feature of the country. In Glendasane several mines have been opened, one of which, the old Luganure mine, was worked in the early part of this century, under the direction of Mr. Weaver; and has, after lying dormant for many years, been lately re-opened, whilst others have been commenced and kept in operation by the Mining Company of Ireland. In Glenmalure, one mine only, which has for a long period been alternately opened and abandoned, is successfully conducted by Mr. Hodgson of Ballyraine, although other adventures have from time to time been set on foot, under occasional appearances of promise.

Above the waterfall in Glendasane, several almost parallel lodes, in a width of 5,000 feet, course within a few degrees of N. and S., and have been explored under the general name of the Luganure mines.

The most easterly of this number, called the *Fox Rock* vein, is only 400 or 500 feet from the edge of the mica-slate, but although opened by five levels on the side of Brockagh mountain, and producing fine lumps of galena, it has not invited extended operations.

The *Moll Doyle* lode, dipping at the unusually low angle of 45° to the west, was accidentally discovered in the bed of the brook a few years since, and has been worked irregularly for lead-ores to a depth of 40 fathoms, and under a length of about 50. Nearly half way between the two small shafts, the vein appears to be dislocated, but no continuous levels have been carried from one to the other.

At 150 fathoms farther to the west, the *Hero* lode, striking N. 5° E. and dipping 60° to 80° west, has been proved with regularity to 80 fathoms in depth, and for about 120 in length.

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of some other mineral whose constituents have been carried off after decomposition, by water, carbonic acid, &c. Mica thus replaces the substance of Felspar, Tourmaline, Wernerite, Pinite, Andalusite, and several others. Vide Blum's *Pseudomorphosen des Mineralreichs*, and Bischof's *Lehrbuch der chemischen und physikalischen Geologie*, vol. ii. p. 1426.

Its average width is 5 feet, but the galena is very irregularly disposed throughout a vein stuff of fragmentary and apparently triturated granite, which is seamed by more or less abundant portions of quartz, associated with zinc blende and calcareous spar in three varieties, one of which is massive, and of a pink colour; the second occurs in transparent tabular crystals, and the third in the tender foliaceous form denominated *schiefer*—or *slaty spar*, of a greenish white colour, and saponaceous to the touch. The lead ore was found principally in two accumulations or "bunches," one of which near the Bog shaft, accompanied the junction of two portions or branches of the lode, and does not appear to have been reached at the 80 fathom level, where the underlie, or inclination of the vein, would throw it 20 fathoms south of the shaft. The north and south continuations of the lode have been proved; in the first case only about 50 fathoms from the shaft; in the second not more than a few feet from the engine shaft.

The *Ruplagh* lode, striking N.N.E., with a westerly underlie, has been explored in three separate mines, the *Hawk Rock*, *Ruplagh*, and *North* mine, of which only the latter is now open; it may be traced for a mile in length, of which some 600 fathoms have been "proved" by mining operations. The Ruplagh mine was sunk by two engine shafts to the depth of 100 and 110 fathoms, and a large quantity of ore was extracted from it; at the south end of the 110-fathom level, a "feeder" of warm water, often considered a precursor of ore, was cut shortly before the catastrophe which occasioned the abandonment of the mine. In 1844, the dry summer so reduced the water of Lough Nahanagan, which supplies the motive power to the machinery, that the pumps could not be kept in action, and the excavations were drowned; whilst it is inferred from the destructible nature of the granite, that all is now in so ruinous a state, as to be dangerous to re-open.

In the North mine a shaft has been sunk on a "bunch" of ore, to a depth of 105 fathoms, at which level the favourable appearances which had excited hopes at 90 fathoms deep dwindled away again, whilst all the levels, or horizontal galleries driven into the body of the granite on the northward, some of them to a very great distance (as the 70-fathom level above 150 fathoms in length), passed along a vein almost entirely destitute

of ore. At the adit level the lode is cut through and very slightly dislocated by a cross vein which courses N.W. by W.

The Hawk Rock, or North Luganure mine, has been opened to a considerable length at the 16 and 26 fathom levels, but to a very small extent at greater depths, where the diminution of the lode to 6 inches wide at 66 fathoms deep, occasioned such disappointment that the mine has, since 1846, been abandoned, like its neighbour the old Ruplagh mine, to the waters.

The average width of the Ruplagh lode is 3 feet, and although it seldom exhibits a regularly banded structure, it is always accompanied by a vein of soft granite varying from an inch to 2 feet in size, which is often bounded on both sides by a "sticking," or thin layer of clay, the "besteg" of German miners. The galena occurs always in "bunches" of small extent, and is associated with quartz, a little zinc blende, and calcareous spar, crystallized in the "vugs," or cavities which have been left in the quartz. White and green lead ore occur near the surface, and may be found on the heaps of mine refuse.

The east and west walls of the lode, which are generally well defined, show but little of that decomposition which often accompanies mineral veins, and both consist of the same kind of granite.

The following is its appearance in the north end of the 56-fathom level:—

Fig. 3.

G Large grained white granite.
g Very soft pink granite.
Q Quartz, fragments of granite, and galena.
s s "Sticking" of tenacious clay.

The water was extracted from both mines by a water-wheel of 24 feet diameter, and 4 feet breast, acting by flat rods from the middle of the valley to the two shafts; and a second wheel of the same diameter and 3 feet breast, effects the raising of the minerals. The neighbouring Lough Nahanagan affords a plentiful supply of water, except in unusually dry seasons, although, by suitable arrangements, it might even at such times be rendered available. On the side of Comaderry mountain, where it has not yet been worked, this lode intersects another called the Luganure, whose course is a few degrees west of north, and has been traced from St. Kevin's road on the north, to the top of Comaderry on the south. A good deal of ore was extracted hence in the early part of this century, some of the bunches being rich enough to produce 3 or 4 tons of ore to the fathom. Several levels of great length have been driven upon it, the latest of which, under the Mining Company of Ireland, was commenced some 2 fathoms beneath the deepest of Mr. Weaver's, but was attended in the first instance with so little success, that the mine had, at the first visit of the survey, in 1846-7, been for some time abandoned.

The only work of preparation for the ultimate trial of the Luganure lode, was an adit level called Richards's, 50 fathoms deeper than that above mentioned, which was continued southwards on the course of the Hawk Rock, or Ruplagh lode, and has now penetrated 275 fathoms into the heart of the mountain, with indifferent success as regards metallic produce, and under the disadvantage of the granite having greatly increased in hardnesss. Quite otherwise was it with the resumption some four years ago of the "old mine," when in the "deep adit" but two fathoms had to be driven before a fine rib of galena appeared, and now that the same level is advanced 400 fathoms from the daylight, and that the ground has been laid open upwards from hence to Weaver's and then again to the Shallow level, a height of 52 fathoms, a most satisfactory proportion of orey lode has been displayed, which, whilst narrowing above, widens out in descending, so rapidly as to give good promise of what may be expected when the deeper level arrives under the same spot.

The general character of this vein closely resembles the Ruplagh: in a width averaging 4 feet, half or two-thirds consists of soft granite, whilst the smaller proportion, which is commonly

attached to the "foot-wall," or lower side, is composed of ribs of quartz, with zinc blende, galena, and occasionally barytes, and calcareous spar. Subsequently to the consolidation of the mass of the vein, it has been subjected to a force which has rent it again cross-wise, and the small cracks thus formed, from 2 to 6 tenths of an inch wide, and intersecting equally the vein-stone and the lead ore, have been filled (sometimes only partially) with blende. Figure 4. represents the typical appearance of this lode; and fig. 4 *a*. the rib of galena and zinc blende on a larger scale.

Fig. 4.

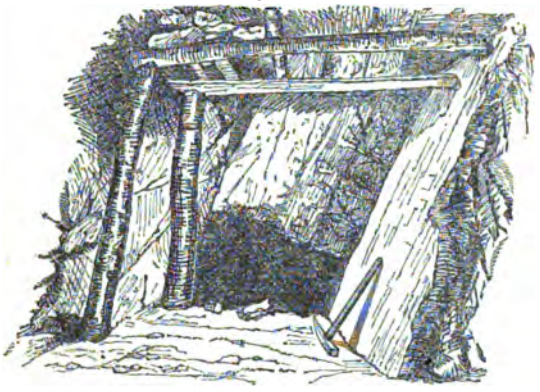
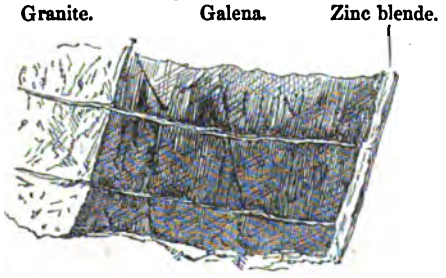


Fig. 4 *a*.



The vein granite is in part so friable that it fills the workings with a heavy sand, and it is commonly so seamed through with slip-faces, or surfaces of friction, smooth and treacherous, from the suddenness with which large masses may unexpectedly fall, that several accidents have occurred from this cause, and would be more frequent but for the speedy opening and re-closing of each "tribute pitch," or working place, brought into action.

During the last five years roads have been constructed up the mountain, railways carried underground, by which a mule

can convey three waggons at a time, a stamps of 16 heads has been erected, and the whole brought into so flourishing a state that about 200 people are now employed under and above ground. The average monthly yield is 120 tons of lead ore, producing 74 to 75 per cent. of lead, and a proportion of silver, varying from 6 to 8 ounces in the ton of lead.

A cross lode coursing nearly east and west, and exposed in the rocks on the south of the waterfall, bears traces of galena and copper pyrites, with a little blende; and induced the commencement of an adit level, which it was once proposed to carry onward for the purpose of intersecting all the above mentioned veins. A plan of this kind, which must have been adopted in any district accustomed to mining on a large scale, was not only likely to discover other lodes intermediate between those already known, but would have reached them all at such depths as to render their unwatering comparatively easy, and to obviate the expense of establishing four engine shafts within the small horizontal range of 260 fathoms, a mode of working so costly as in great part to have swallowed up the proceeds of the lead ore which was extracted during the prosecution of the Ruplagh mines.

In the granite precipices which hem in the upper end of the romantic valley of Glendalough, a powerful vein courses E.N.E. and W.S.W., advancing on the one side towards the mica slate at the boundary of which it appears to terminate, and disappearing on the other side above the waterfall of the Glenealo river. At the latter place it consists of a dyke of soft granite, accompanied by quartz, and by sparry iron ore or carbonate of iron to the width of 8 feet, spotted occasionally with copper pyrites. This ore, used with great advantage in some of the southern countries of Europe for the production of excellent descriptions of iron, would here, from the remoteness of smelting furnaces, not be worth extracting; if, however, some convenient and economical mode of pressure should render available the large tracts of peat bog which extend without interruption for many miles on the west, the sparry ironstone smelted by that fuel would yield an iron of superior quality; and it would only remain to be proved whether the ore be present in sufficient quantity to warrant the commencement of operations—a point which seems to me, notwithstanding the

appearances at the surface, to be rendered very doubtful by the changeful character of the vein.

Among the cliffs on the side of Comaderry mountain the quartz greatly predominates, and in some places, with a width of above 5 fathoms, rises boldly to a height of several feet above the softer granite in its neighbourhood; the structure of many portions of it is spherical and radiated, the crystallization appearing to have acted from many centres simultaneously. Copper pyrites and galena are sparingly interspersed in the mass, which is generally so hard as to render its profitable opening hopeless. Mr. Weaver, indeed, relates that a clump of galena, weighing about a ton, was found near the surface, where the vein enters the mica slate and encloses fragments of that rock, but the general body of the quartz belongs to the category of the "harsh" and "uncongenial ramps" of the practical miner.

Within the last few months Capt. Clemes, the agent for the Mining Company, has discovered a north and south lode among the granite precipices at the head of Glendalough, about 80 fathoms west of the spot where the old Luganure vein would be expected to emerge; and a level which has been commenced upon it, only 7 feet higher than Richards's level on the other side of the mountain, has already yielded some highly promising stones of lead ore. A second level has been opened about 46 fathoms lower down, and the piercing of the entire mountain by these galleries at so great a depth below its crest, is calculated, if persevered in, fully to explore its resources, and will probably lay the foundation of a mine which may be wrought with advantage almost for centuries.

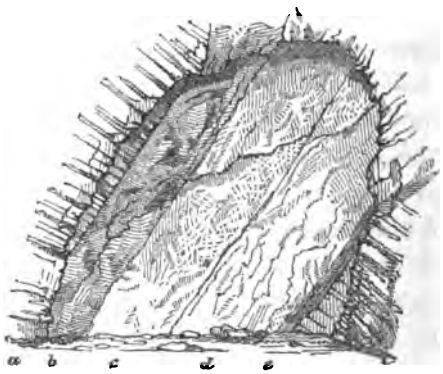
This lode also carries a rib of decomposed granite on its hanging side; and the ore is associated with quartz, baryte, and with, what is unusual in this district, fluor spar of a green tint, and very friable.

Higher up the valley, lead ore has, in inconsiderable quantity, been raised from two localities, the one on the west of a small patch of mica slate, where the lode courses nearly N.N.W., the other farther to the south, where a shaft has been sunk to the depth of 10 fathoms, and some large orey masses extracted but its high and exposed position, which has procured it the name of "Van Diemen's Land" among the miners, has also up to this time been an obstacle to its further examination.

In Glenmalure the phenomena differ materially from those we have been considering; not only is the granite seamed with long strips and patches of included slate, but the lodes, instead of forming a system either parallel with or perpendicular to the meridian, vary considerably from those lines of direction.

The principal vein strikes through the townland of Ballinafunshogue about S.E. by E., and has been proved for above 3,000 feet in length, though little more than a third of that extent has been actively operated upon. At the surface its hade or underlie is towards the south, but, by a return angle to the north as it descends, it remains, on the whole, vertical as far as the adit level, below which it inclines continuously to the north. The dimensions are far more considerable than in the lodes of which we have treated above, sometimes reaching even the width of 3 fathoms, and continued through both granite and slate without particular diminution in one or the other. Three or four distinct bands of various material may always be distinguished, one of which is always without ore, and is evidently due to mechanical action, inasmuch as it is composed of débris of the rock through which the lode at that place is coursing, whether granite or mica slate. Thus, in the accompanying figure, taken at the east end of the 35-fathom level, where both walls of the vein are formed of soft and blanched slate, the central part, of 3 feet in width, consists of fragmentary and triturated mica slate.

Fig. 5.



a Slate, wall of the lode.
b Galena and zinc blende with spots of copper pyrites.
c Broken slate, with slickenside parting on the left side.
d Irregular ground gith quartz and spots of galena.
e Four-inch rib, principally galena.

The portion *c*, "soft" or "vein" ground, is so much less hard than the rest of the lode, or the "country," that the levels are driven in it at a comparatively small expense. The "slickenside" or polished face between *b* and *c* is scored with striæ which dip 20° to 30° N.W., or make a plane angle of 75° with the direction of the hade of the vein; showing that if, according to the generally received explanation, these smooth surfaces and grooves are due to the friction caused by the mass on one side of them moving up or down with respect to that on the other, in this case the motion has not taken place in the direction of the hade or underlie of the vein.

In the shaft which is sunk from the adit level, the lode is filled to a great width with hard quartz, but yields ore both on the east and west of it, presenting in the 25-fathom level a width of three feet of almost solid galena, between walls of mica slate. It is observable that when Mr. Weaver wrote, it had been remarked that the vein "proved the most productive in that part where it traverses a very thick bed of mica slate."

This fine mine has suffered under the disadvantage of being at various periods worked in an unskilful manner, which has entailed difficulty and expense on later adventurers; that portion of the lode extending from the surface to the adit level has been almost entirely removed, but in a most irregular way, and the whole is in so ruinous a condition, that it is impossible to approach either of the "ends" or extremities of the workings, on which alone an opinion of the farther resources of the vein can be founded.

The position also of the adit and shaft with respect to each other is so ill-chosen that the apparatus for raising water and minerals is in consequence very disadvantageously applied, and the expenses therefore bear an unnecessarily high ratio to the profits.

In the adit, where the occurrence of numerous strips of slate gives rise to an appearance of its interstratification with the granite, an east and west lode has been intersected, which contains a little galena; and at the back of the old smelting house another, coursing nearly E.N.E. is crossed by the Ballinafunshogue vein. It consists of a dyke of disintegrated granite, with a 4-foot band of hard quartz containing spots of galena, zinc blende, and iron pyrites, with which is associated fluor spar,

otherwise scarcely ever seen in the district, in small cubes of a purple tint.

In the neighbouring townland of Cullentragh Park, a lode runs N. 23° W., consisting of one foot of quartz spotted with crystals of galena, and of a vein of coarse granite, from an inch to a foot wide, on the north wall. On the eastern side of the small workings which have been made upon it, it is met by a cross joint, and lost to view.

On the south side of the valley, nearly opposite to the above, three veins have been slightly operated on, not agreeing in direction, though having one characteristic in common, the presence of baryte, which in two of them occurs in ribs of sufficient width and purity to have been made the object of extraction. They all present galena and zinc blende in small quantities, minerals which in the Clonkeen townland are associated with sparry iron and small spangles of micaceous iron, a substance often met with among ores of copper, although very rarely among those of lead.

Since 1846 a considerable trial has been carried on in the townland of Baravore, upon a strong lode, coursing E.S.E., and bearing galena with zinc blende, copper pyrites, black oxide, and carbonate of copper. It is at present abandoned; but operations have been commenced at four different levels on a north and south lode in the townland of Ballynagoneen, on the north-eastern side of the valley, bearing at intervals the same ores associated with a rib of quartz, which lies on the foot wall, and varies from 6 to 18 inches in thickness. In the "end" of one of these levels was instructively exhibited a vein of about 2 inches wide of almost pure, white, largely foliated mica, which had evidently, after the consolidation of the rest of the lode, crossed through the quartz rib, as well as, more indistinctly, through the soft pink granitic substance which formed the hanging side. This mica vein, however, as well as the rest of the lode, had subsequently been cut through by small fissures, now filled with clay or "flucan," and parallel with the walls of the main vein, which generally were well defined.*

* This vein is referred to at p. 352.

Fig. 6.

G Granite of the "country."
G′ Softer granite of the vein.
Q Quartz, with a little galena.
M Vein of mica.

Near the head of Glenmalure, in the townland of Camenabologue, and in the main body of the granite, veins may be observed at two or three places, bearing nearly E.S.E. and W.N.W. They offer no more than traces of sulphide ores, but present, in a marked manner, the same order of parallel ribs of softer granite, which we have pointed out as accompanying the other lodes. The figures appended represent these appearances at two spots, one in the bed of the stream, the other a little to the north of it.

Fig. 7.

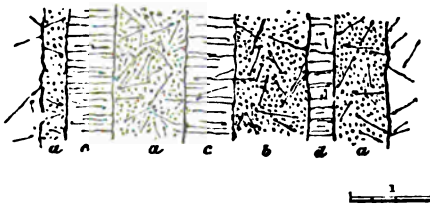
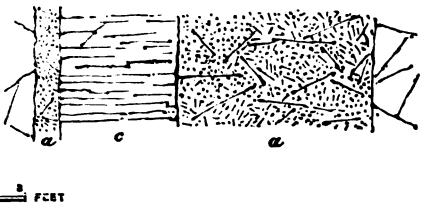
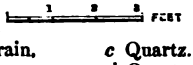


Fig. 8.

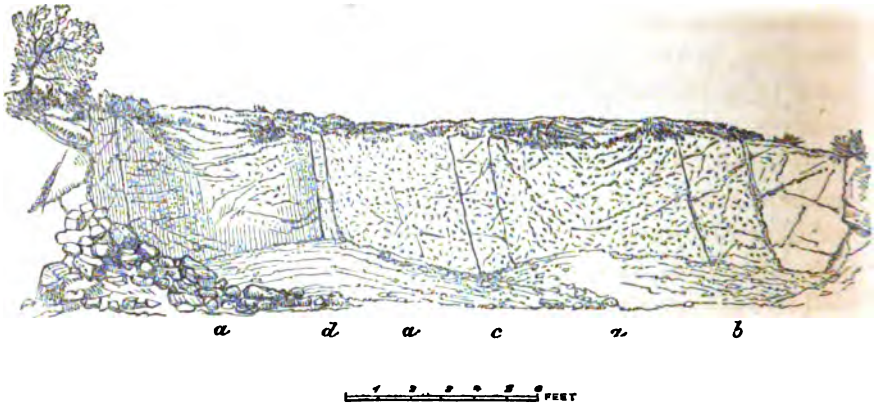




a Soft Granite, of medium grain.
b The same, with a green tint.
c Quartz.
d Quartz, with specks of copper pyrites.

To the south of Glenmalure, there is only one locality in which lead ore has been found in the granite, viz.: in the side of the waterfall of the Ow River, above Aghavanagh Barrack, where the lode courses somewhat differently from the above mentioned groups, about E. 40° S. At the point where it is best exhibited the orey member of the vein is but 3 inches wide, bearing a very small relation to the magnitude of the whole, as may be seen in the accompanying diagram:—

Fig. 9.



a Granite of sandy character.
b Coarse granite with pink felspar.
c Granite containing much steatite.
d Quartz with spots of galena and copper pyrites.

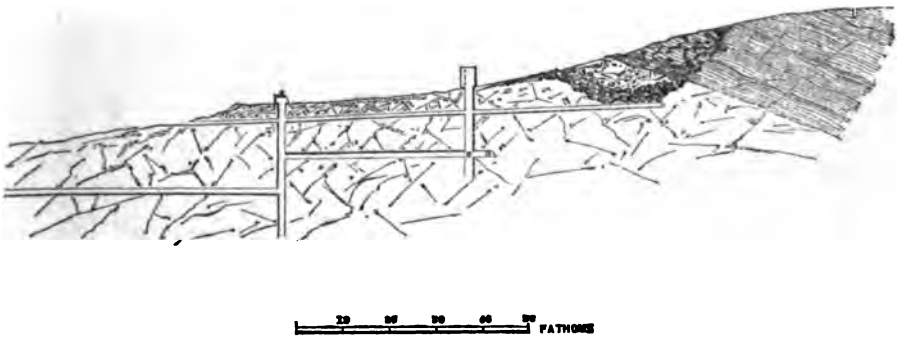
Northward of the two principal mining valleys, and always near the junction of the granite and mica slate, lead ore has been found at several points, at some of which mining operations have been commenced and again abandoned. At the western end of Lough Dan, a lode coursing N.E. by N. and hading 70° S.E., is composed of two parts; first, a 2-foot rib of quartz with spots and strings of copper pyrites, galena, and zinc blende; and secondly, 6 to 10 inches of soft decomposed granite, generally occurrring on the hanging side. In the levels which have been driven, without much success, upon the vein, it is remarkable that, as we approach the overlying mica slate, fragments of that rock form the filling matter of the lode instead of the friable granite; notwithstanding which, some trenches cut in the slate at the surface have failed in proving that the fissure has been continued more than a few feet in the latter rock.

On the western shore of Lough Tay, a small vein bearing nearly E. and W. exhibits a little galena with iron pyrites, and has occasioned some inconsiderable trials, as have also similar appearances at Djouce and Powerscourt.

At Ballycorus and Rathmichael, in the county of Dublin, several lodes, with a prevailing strike of E. by S. or E.S.E. have yielded small quantities of galena; but only that in the former townland has been systematically opened. The principal vein averages no more than one to two feet in width, and consists of quartz with baryte, galena and zinc blende; but the circumstance which of late attracted most attention was the discovery, in the principal shaft and below the level of the deep adit, of a rib containing native silver; where its occurrence, being in mossy and capillary forms disseminated through a band of greenish quartz about an inch wide, is apparently not the immediate result of the decomposition of the sulphuretted ores, as we have reason, in the case of most of the native metals of our own islands, to infer.

The lode at Ballycorus has been traced for many fathoms into the mica slate, and formed, on approaching that rock, a very productive "bunch" of ore, which has been removed by a surface excavation or "open cast." The accompanying section on the course of the lode will illustrate its geological position :—

Fig. 10.



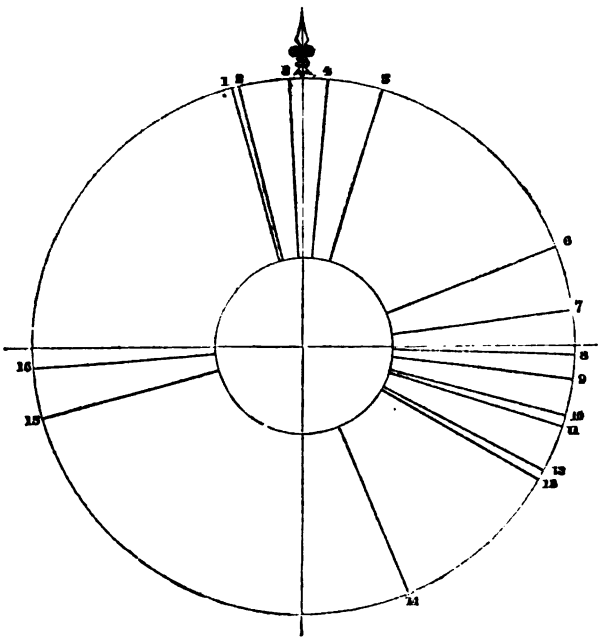
At a distance of 300 or 400 fathoms N.N.W. of the above mentioned workings, it was sought to take advantage of a quartzose vein bearing southward, in order to drive a deep adit level into the Ballycorus mine; but through inadvertence in

piercing a deep accumulation of gravel and sand, the work was ruined shortly after its commencement.

On the coast, at Dalkey, the same geological boundary line is again marked by a lode producing galena and zinc blende, and formed, in great part, of disintegrated granite: from the sea cliff small workings have been opened, but have for many years been abandoned, although according to Dr. Rutty's "Natural History of Dublin," (1772,) some hundred tons of lead ore were obtained from this spot.

If we now take a general review of the above detailed phenomena, although systems of lodes cannot here be distinguished by their filling substances, we shall arrive at a few inferences which may tend to confirm certain positions necessary as a foundation whereon shall be one day reared that oft attempted but slightly advanced superstructure, a theory of mineral veins. In the first place, a ridge of granite mountains striking N.N.E. is skirted on its eastern flank by mica slate, whose outer edge runs in the same direction; and along the line of boundary, for a distance of 30 miles, mineral veins have been discovered at intervals. Secondly, a great portion of these lodes is always composed either of a granite differing from that of the mountain mass, or of a decidedly disintegrated granite; proving, in both cases, that fissures have been opened, and then filled either by injected dykes of newer granite, or by the re-constituted minerals or by water-borne detritus of the older; the latter hypothesis being supported by the few cases in which fragments of mica slate are found where the vein enters that rock. Thirdly, the majority of the veins occupy lines which bear some relation, on the one hand, to the direction of the Wicklow chain, and the strike of its stratified rocks; on the other, to the line of the meridian; and whilst the former circumstance has doubtless some connexion with the origin of the fissures, the latter has probably exerted an influence on their filling with mineral substances.

Fig. 11.



No. 1. Lode of Upper Glendalough.
2. Fox-Rock, Glendasane.
3. Luganure.
4. Hero.
5. Ruplagh.
6. Glendalough.
7. Glendasane.
8. South lode, Glenmalure.
9. Ballycorus.
10. Camenabologue.
11. Ditto.
12. Glenmalure, (Ballinafunshogue)
13. Battery.
14. Cullentragh Park.
15. Lode above the smelting house.
16. Clonkeen.

In the above diagram, the upper semicircle includes the courses of the lodes of Glendasane and Glendalough, as referred to the true meridian, whilst the lower one exhibits those of Glenmalure and Ballycorus. The first point which presents itself to our notice, is the decided division into two groups, of which one approximates to the line of the magnetic meridian (which is known within 235 years to have oscillated through an angle of 36 degrees), whilst the other group deviates only slightly from a direction perpendicular to the above. We may be unable, in the present state of our knowledge, to follow up this distinction with the consequence which it deserves; yet it remains a significant fact not unworthy of record.

The perpendicularity of one group to the other, considered without reference to the direction of the magnetic needle, has

been proved by Mr. William Hopkins of Cambridge, in his admirable researches in Physical Geology, to be a necessary result of the upheaval of a mass of three dimensions, acted upon by two systems of parallel tensions. These investigations have reference mainly to the elevation of districts of stratified rocks, but are applicable to the area of massive rock, granite, under notice, whether we consider it under its present denuded aspect, or covered as it probably at some time was, by a crust of slatey strata. Some of the conclusions drawn by him are thus stated:—"If the mass be subjected to two systems of parallel "tensions, of which the directions are perpendicular to each "other, two systems of parallel fissures may be produced, of "which the directions will be perpendicular to each other. No "two systems of parallel fissures could be thus formed, of which "the directions should not be perpendicular to each other." Moreover, "One system might be formed at any time sub-"sequently to the other."

There is no *exact* coincidence between the longitudinal veins before us and the axis of elevation; but the approximation is sufficiently close, if we take into account the irregularities which might be produced, either by the variable character of the elevated mass, by the sinuosity of the axis, or by the unequal intensity of the elevatory force at different points. A reference to the published map of the Geological Survey, will show that it would not be difficult to reconcile the discrepancies existing between the actual direction of the veins and that indicated by the above laws, if we might assume that the axis of disturbance passed in a curved line from the south-west to Mullacor mountain, and thence towards Tonelagee.

Viewing then the north and south lodes of Glendasane as the longitudinal, we may consider the east and west veins to be the transverse fissures which approximate (Hopkins, § 57) to the dip, as do the former to the strike of the stratified beds. We do not, indeed, find that the observation stated in Mr. Hopkins' introduction (II. 8), holds good in the Wicklow range, that a "large proportion of the most productive mineral veins are found in the transverse system. The longitudinal (frequently termed by the miner *cross courses*) carry ore very irregularly." Nor have we sufficient evidence of the formation of one set being posterior to that of the other, neither of them being re-

markable for greater regularity or for a peculiar grouping or collocation of minerals.

Concluding, however, with Mr. Hopkins (§ 44), that if we conceive an additional force superimposed on a uniform force producing the general elevation, the longitudinal fissures may be formed first, and a transverse system may be produced at the next instant, or at any succeeding epoch, we shall probably have the true explanation of the phenomena before us; this conclusion will, however, in our case stand in opposition to that announced in § 70, by which he combats a common opinion of miners, that the dislocation of one lode by another affords a test of their relative age. The *Hero*, *North Rupplagh*, *Fox Rock*, and *Luganure* lodes are all dislocated by east and west veins, carrying a small proportion of lead ore; and therefore both the theory of the later date of the transverse fissures, and the ordinary notion of the earlier formation of those which are dislocated concur at this place, in assigning the earlier date to the north and south lodes.

It has here been taken for granted that all these veins have been formed by the gradual crystalline accumulation of various mineral substances within fissures previously formed, since no other view appears to be tenable or even explicable; but as regards the origin of such fissures, it must be admitted that phenomena are observable which may be so interpreted as to render that origin less distinctly dependent on the action of an elevatory force. The direction of the north and south lodes coincides very nearly with that of the principal divisional planes or "joints," which intersect the granite, and range on the average between N. 5° W. and N. 10° E. through a large part of the ore-bearing district.* It *might*, therefore, be argued that the granite was thus "jointed" prior to the opening of the vein-fissures, and that the direction of these latter was influenced by the planes of division already existing. Yet from the great uncertainty which at present prevails respecting the causes and dates of the "jointed" structure, such a mode of reasoning would only carry us farther back into obscurity; and it is,

* Professor Sedgwick, in 1821, observed the parallelism and nearly meridional course of the joints in the granite of south-western England. Cambridge Phil. Trans., vol. i. See also Enys on the Penryn granite, Phil. Mag. 1833, and De la Beche, Geol. Observer, 2d edit. p. 625.

perhaps, not unphilosophical to infer, from the marked relation borne by both these phenomena,—the vein-fissures, and the joints, to the axis of elevation of the country, that we must seek for an explanation of the facts in inquiries analogous to the above, but in which the operation of some molecular arrangement must be superadded to mechanical action.

I have dwelt at some length on this subject, inasmuch as the strike of the most productive veins, although in the cases noticed, diametrically opposite to that observed in most of the well described mining districts, may after all be governed by the same laws, if we regard only a different direction of the elevatory forces, and of the tensions consequent on their action, at any given period.

Mines of the Slate District.

The clay slates which form the principal constituent rock of the county of Wicklow are not, as a whole, remarkable for the presence of metallic minerals, either disseminated, or in veins; but a band or "channel" of about 600 fathoms in width, coursing from the north flank of Croghan Kinshela for about 9 miles in the direction N. 40° E., exhibits at intervals a variety of metallic ores, which being in certain spots accumulated in larger quantities than elsewhere, have given rise to the long-continued mining operations of the Vale of Ovoca.

The slates in question, which from the fossils occurring near Rathdrum, are referred to the lower Silurian period, are thinly laminated, and very uniform in strike and dip, though differing so much in mineral composition as to pass through many gradations of argillaceous, talcose, felspathic, and greenstone slate. Considered under a general aspect, the hornblendic varieties occur chiefly on the lower or "lying" side of the metalliferous portion, whilst the hanging side is occupied, on both sides of the Ovoca, by extensive roughly bedded masses of a felstone, or silicious felspar rock, which gives rise to most of the precipitous forms between the Meeting of the Waters and the Wooden Bridge.

Commencing with the south-western end of the line in question, we find in Ballycoog and Moneyteige hills, that small workings have long ago been commenced, and from time to time resumed, on beds of magnetic and oligist or specular iron ores, associated with copper pyrites, quartz, and chlorite. These deposits are in each case two in number, at a small distance apart, and varying from a few inches to 6 or 8 feet in width. The copper ore near the surface is too sparingly mixed to occasion a profitable extraction, and the iron ore, rich though it be, has not been proved to exist in sufficient mass to render larger operations advisable. The same veins, on the banks of the Aughrim river, present but small threads of pyrites; but at Knocknamohill and two other points within a mile to the north, deposits of an analogous nature, bearing much the same direction, but not in a continuous line, exhibit considerable quantities of specular iron ore, and iron pyrites associated with quartz and chlorite, and interspersed with small patches of copper pyrites. Farther to the north-east, however, in several parallel lines, these indications become more pronounced, and the veins, interrupted only by a large fault, are continuously worked along an extent of 2 miles, varying occasionally in the number of workable deposits as well as in the nature of the minerals exhibited.

There is, perhaps, no tract in the British islands which exhibits, even to the eye of the uninitiated, an appearance so strongly stamped with the characteristics of the presence of metallic minerals. For a considerable distance on both sides of the deeply-cut valley of the Ovoca the face of nature appears changed, and instead of the grassy or wooded slopes, or the gray rocks which beautify the rest of its course, we see a broken surface of chasms, ridges, and hillocks, glowing with tints of bright red and brown, or assuming shades of yellow and livid green, which the boldest artist would scarcely dare to transfer to his canvas. Here and there from among the ruins peers the white stack and house of a steam-engine; or water-wheels stand boldly projected against the hill-side,—some still and neglected, others whirling round in full activity; long iron pump rods ascend the acclivities to do their work at distant shafts, and as long as daylight lasts, the rattle of the chains for raising the ore, and the clink of the separating hammers attest the vigour of the operations. In truth, quite independently of the geological or

mining interest of the place, a walk through this series of mines, especially on a sunny evening, will yield a harvest of novel and striking scenes, the effect partly, of the features of the mineral ground, and partly of the fine distant prospects which the higher workings command.

The first of these mines on the west is Ballymurtagh, at present in the occupation of the Wicklow Copper Mining Company, and producing large quantities of copper ore and iron pyrites. The surface has been marked by huge projecting masses of "gossan," or hydrous peroxide of iron, resulting from the decomposition of the ores, but has been much changed in appearance by the great activity of the operations during the last few years. The principal feature is the great metalliferous deposit which dips with the slate at angles of 40° to 60° S.E. and consists, at a small depth from the surface, of 12 feet in width of granular iron pyrites, locally termed sulphur ore, of a pale colour, altogether free from gangue or veinstone, not bounded by distinct walls, but ceasing by gradual interlamination with the clay-slate. On the north to the distance of 100 fathoms, and on the south for 20 fathoms, parallel veins of cupriferous pyrites have been met with, sometimes very numerously; but only in the case of those which lie within a distance of 50 feet to the south, profitable in extraction. The iron pyrites has not been found in available quantity at a greater depth than 100 fathoms; it appears to grow thinner at about 80 fathoms from the surface, and then to unite with the copper "lodes," as they are termed, on the south, forming together at the 56-fathom level a "bunch" of copper ore, 24 feet in width. This vein was in one spot by the addition of numerous bands of greater or less thickness, and on both sides, increased to nearly 60 feet, and had been worked away in one huge cavity of such dimensions as are rarely seen in metallic mines.

The copper "lode," although varying much in thickness, has none of the characteristic appearances of a vein; its ore is the double sulphuret of copper and iron or ordinary copper pyrites, and is of a very low per-centage owing to the admixture of iron and of portions of quartz and talcose or sometimes chloritic slate, never occurring in a fragmentary state, but interlaminated sometimes so delicately as to appear in fine films, and contorted like the adjacent rock. It may even be remarked of the masses

or "cobs" of ore brought to the surface, that when struck with a hammer they have no tendency to break with the usual fracture of copper pyrites, but split in the direction of the lamination.

As an exception to these appearances, a cross-fissure, the sides of which were encrusted with crystallized copper pyrites and quartz, was found between the 33 and 66-fathom levels; with a course nearly at right angles to that of the main lode, it came up to, but did not pass its north wall, and thus presented a character analogous to certain veins which will be described in Tigroney mine. Its width was irregular; yet was sufficient to enable it to be worked "on tribute" for some 20 fathoms in length.

In the western portion of the mine, which has not long been opened, the copper lode has been found in good force, and produces a better description of ore; in the 100-fathom level, at the new shafts, it is as much as 6 or 8 feet wide, and the walls, as usual, are ill-defined, from the "country" being impregnated with ore on both sides of the main deposit. Even in the bottom of the 110-fathom level, which is but lately completed, fair "bunches" of ore are seen.

On the surface of the hill, about 120 fathoms to the north of the principal vein, large masses of "gossan," composed chiefly of fragments of slatey rock cemented by brown oxide of iron, had long ago induced the commencement of mining operations. It is, however, only within the last three years, that more efficient trials have been crowned with the success of discovering a parallel course of iron pyrites of remarkable size and solidity. Two principal shafts have been sunk upon it to the respective depths of 40 and 60 fathoms, and a third has been commenced with the view of intersecting it at a depth of 60 fathoms, further westward. "Levels" or galleries have been extended in it at the depths of 20, 30, 40 and 60 fathoms to lengths varying from 20 to 30 fathoms, and the whole of the ground thus opened proves to be productive, the breadth of the new lode averaging 24 feet.

With the view of working this fine discovery to the greatest advantage, an adit or water gallery, called Margaret's level, has been driven up so as to intersect the north vein at 60 fathoms deep; and another which will unwater it to a very much greater

depth is driving from the road side, nearly at the level of the river, in a vein offering appearances of considerable promise.

Two intermediate lodes have also been discovered by the same operations, one of which offers a good width of iron pyrites with 1½ per cent. of copper, and occasional ribs of higher produce.

By the kindness of E. Barnes, Esq., M.R.I.A.,* the resident director, the survey has been furnished with the following Table of the Statistics for eight years previous to 1852.

PRODUCE of BALLYMURTAGH MINE, County Wicklow.

Year.	Copper ores.	Sold at Swansea.	Sold at other ports.	Gross value.	Pyrites.	Net value.	Paid in wages.
	Tons.	Tons.	Tons.	£	Tons.	£	£
1844	7,130	3,635	3,495	18,166	9,575	7,420	14,429
1845	6,816	2,836	3,980	17,871	11,943	9,337	14,885
1846	7,318	2,564	4,754	16,046	11,023	9,445	14,395
1847	6,012	964	5,048	11,851	13,503	12,928	13,795
1848	7,621	1,317	6,304	15,022	8,969	9,865	—
1849	7,783	1,233	6,550	15,342	9,582	10,540	—
1850	6,754	339	6,415	13,313	14,873	16,360	—
1851	6,026	102	5,924	11,878	21,738	23,911	—

About 800 persons have been in constant employment, from 300 to 400 of whom worked underground.

With regard to the working of the mine, unskilful methods were employed for many years, which have repeatedly endangered the whole of the underground ways and those engaged in them. The practice of "underhand stopeing" was always adopted, from unwillingness to allow time and money for properly opening out the ground, and conducting the operations on the principles recognized as the best in Cornwall, Saxony, the Hartz, &c. During the last few years, the system of "stopeing in the back" has been introduced, a pair of shafts have been sunk at the extreme western end of the mine, and the 110-fathom level is to be driven at once beneath all the old workings, by which means

* I may here express my obligations to this gentleman and his agent, Captain Roberts, as also to Mr. Petherick, and Captains Barratt and Clemms, of the Luganure mines; to Mr. Hodgson and Captain Webster, of Ballygahan; Captains Reid and Lane, of Tigroney; and Captain W. Roberts, of Connaree mine, for the facilities afforded in the mapping of the surface and in the underground examination of these mines.

the stability of the mine, from a certain depth, will be ensured; and the water which must at present be raised by horizontal rods from all the "bottoms" will be lifted in a direct line.

The large dimensions of the excavations, precluding the aid of timbering, have caused terrific crushes, attended fortunately as yet by no loss of life. In 1835 a great fall of the solid iron pyrites occurred; from the roof of the 18-fathom level, a mass 30 fathoms long, and 20 fathoms deep, (at an average of 10 feet wide, weighing near 30,000 tons) broke away, and crushed through all the levels to the bottom. The previous sounds of rending and the smell of sulphur diffused by the friction, warned most of the men to escape; and even the rats, which were living in great numbers underground, fled to the surface; 18 men, however, who took refuge in a freshly driven gallery were immured at a great depth from the surface, and extricated only after a couple of days passed in the most frightful anxiety, by an orifice accidentally left, and found to extend throughout the heap of ruins.

On St. Patrick's day, 1845, at 10 P.M. when no one was in the mine, another tremendous "run" occurred near the eastern boundary. Extensive workings had been carried on by the "old men" in the copper lode, and had been filled up with "deads," or refuse stone; from the absence of plans, however, their actual extent was but little known, and yet they were divided by a parting of only a few inches thick from the modern excavations in progress on the "sulphur course," where the latter was very wide.

Fig. 12.

A few heavy "slobs" or platey masses had fallen down previously; but on this night the whole barrier gave way, and the old "deads," solid as they were, broke in like a stoney torrent, and forced their way down to the 33-fathom level, forming a mass of shattered rubbish from the surface to a depth of 70 fathoms, and swallowing up in the vortex various buildings

which had been erected over it. Had the event occurred on a working day, 30 or 40 men must have been killed.

A considerable force of machinery is employed at Ballymurtagh, consisting of, 1st, a Cornish pumping-engine with a 51-inch cylinder at the western shafts; 2d, the old eastern engine, with a 30-inch cylinder driving a whim, and also 24 stamp-heads; 3d, two whim-engines of smaller dimensions. It is remarkable that notwithstanding the poorness of the ores, no mechanical power is at present brought to bear on their "dressing" or preparation for the market; and apparatus which in other copper mining districts is largely employed for that purpose, is said both here and on the eastern bank of the Ovoca to have been tried and rejected. The peculiar flakiness of the ore, and its great admixture with iron pyrites, operate as causes of difficulty, and the quickness of the boys engaged in hand-picking enables the ore to be "cobbed" and picked for 6*s*. a ton.

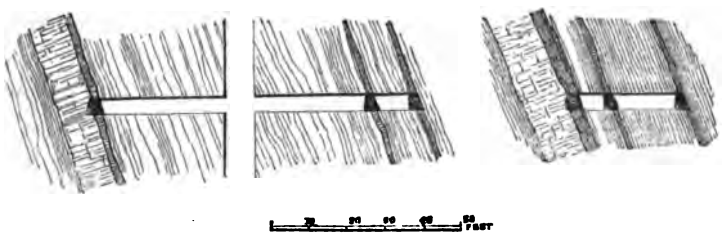
In the second of the Ovoca mines, Ballygahan, worked by Mr. Hodgson of Ballyraine, the same general characters are continued. The pyrites deposit, which near the surface averages 3 fathoms in width, swells out at the deep adit level, west of the "Blue shaft," to 36 feet, exclusive of a south rib of 4 feet, containing a proportion of copper pyrites; and at the deeper levels, 60 and 70 fathoms below the adit, diminishes to 2 or 3 feet. The "coppery rib" above mentioned is succeeded at 9 fathoms farther south by the "main lode," (which above the adit level has also a "north branch,") at 2 fathoms again by "Barry's lode," and at 2 fathoms farther by "Tukes's lode," all of them irregular deposits of copper ore, without very definite walls or the admixture of the vein-stones characteristic of mineral veins. The "copper lodes" have long since had all their most profitable parts extracted, and the cavities are filled with "attle" or refuse (remblais of the French), which has become strongly cemented together by the oxide of iron deposited by the mine waters in consequence of the decomposition of the pyrites; they have been almost neglected since the demand for "sulphur ore" arose, and have therefore not been investigated to the same depths as the principal or "champion" lode.

Westward of the engine shaft, 112 feet, the pyrites course is met by a "slide" pointing a few degrees west of north, and is heaved to the south a distance of 55 feet, whilst the "copper

lodes" appear to be unmoved by any dislocation, and are thus much nearer to the great deposit in the western, than in the eastern part of the mine.

Thus fig. 13 will represent a vertical section, in a south-east and north-west direction, of the several veins as seen at the engine shaft, in the 18-fathom level, and fig. 14, a section of the same veins in the 15-fathom level above the adit, at Brownrigg's shaft, the distance between the two sections being but a few fathoms.

Fig. 13. Fig. 14.



This remarkable point, to which we shall again advert,—one of the very few which afford a proof of the introduction of the mineral veins being subsequent to the deposition of the slatey rocks, is, with many of the concurrent phenomena, clearly exhibited in the 6-inch map from which the geological lines of the published map of Wicklow have been reduced, whilst the principal workings, and the very interesting transverse sections afforded by these several mines, are represented on a larger scale in the separate sheet of the Ovoca mines published by the Geological Survey.

About 15 fathoms east of the "Blue shaft" the "sulphur-lode" is heaved a few feet to the north; and 30 fathoms farther, two more dislocations occur, the fragment of lode being in each case about 2 fathoms long, and separated from the other part about 3 fathoms. Towards the river, it seems probable that the more considerable disruption takes place, which heaves or throws the beds in a horizontal direction to the northward, to Tigroney mine. Immediately to the south of Ballygahan mine, the ordinary slate is succeeded by the silicio-felspathic masses forming the "Bell rock;" and some uncertainty has been felt as to whether this rock would interfere with the continuation of the metalliferons beds in their prolongation beneath it. It

would, however, now appear that it overlies the slates in the sense of their stratification, and therefore would probably exert no influence on their productiveness.

Ballygahan is relieved of water by an undershot wheel placed in the bank of the Ovoca, whilst a water-wheel of 50 feet diameter, and 30 inches breast, draws from the engine shaft; and a double wheel of 32 feet diameter, with 15-inch buckets, from the "Blue shaft."

The iron-pyrites has been, till within 2 or 3 years, judiciously extracted from chambers of limited length and height, between which "arches" of sufficient strength were left to sustain the walls; and in this manner Ballygahan long escaped the terrible "runs" which have endangered its neighbour mine.

The increased demand for "sulphur-ore" since 1846 induced the managers to cut away some of the buttresses which had hitherto given security to the excavations, and the almost inevitable result was that a terrific crush took place in May 1850, which engulphed the surface, with a house standing upon it, and an unfortunate child that had not fled in time from the treacherous spot; and this, coupled with the minor settlements which have since taken place, has given to the hill side the appearance of a frightful ruin.

On the northward, to the distance of half a mile, ores of a similar nature, but in small quantity, are occasionally mingled with the slates; and at Kilcashel and Upper Ballymurtagh have given rise to extended mining trials.

On the eastern side of the Ovoca, at the mines of Tigroney and Lower Cronebane, the beds of decomposing and variously coloured slates, together with the "sulphur course" and the "copper lodes" on the south, are evidently the continuation of the deposits of Ballygahan, dislocated to the horizontal amount of about 1,000 feet.

The iron pyrites runs to 20 feet in width; and the clay-slate at its side is for 3 fathoms of a dark colour, smooth, and softer than at a greater distance. During the great demand for sulphur in 1841 and 1842, upwards of 2,000 tons of this ore were raised per month. In 1846 the work was concentrated upon the copper ores, but subsequently the pyrites has been very largely extracted. At greater depth, the main deposit again seems to diminish; and in the 10-fathom level (below the

adit which mouths a few feet above the level of the river) it presents a width of only 14 inches, with the accompanying appearance.

Fig. 15.

In the above figure the light coloured band represents the iron-pyrites; the narrow ribs with transverse lines are "strings" of slightly cupreous iron-pyrites.

The "copper lodes," which are very irregular, but more or less parallel to the pyrites course, commence almost immediately on its south wall, and are sometimes seven in number, besides occasional intermediate ribs, within a width of 20 fathoms, so that the ground is worked away in stopes of 14 or 15 feet wide for considerable distances. The ore is in general tolerably clean, but only produces from 4 to 8, and rarely 10 per cent. Cross-cuts, driven 20 fathoms farther to the south, have not met with any metalliferous deposit.

Near the first "copper lode" the slate is often much wrinkled, though its general inclination is 60° to 70° S.E. The lode is in most respects similar to those above described, but is here sometimes interrupted by a cross deposit of limited length, which appears to stop it for a time on its line of strike, as in the figure.

Fig. 16.

Such T's, as they are called by the miner, are productive of copper ore of somewhat higher per-centage than that before mentioned, associated with a little quartz and chlorite; and

extend in the cross portion to a length of 8 or 10 fathoms, and heighth of 20 or 30. They possess also a high importance, in any considerations on the nature and origin of the metalliferous deposits of the Ovoca, for they clearly prove that other forces have been superadded to simple deposition,—a fact not so distinctly elucidated on the western side of the river, although paralleled in one case by the cross fissure at Ballymurtagh, adverted to in p. 373. Such richer parts have been described by Weaver as "contemporaneous veins," bearing copper pyrites with 10 to 12 per cent. of copper, and sometimes a width of 4 or 5 feet of solid ore.

Towards the N.E., beyond the "Mosey" shafts, the strike of the beds appears to have suffered some disturbance, and their continuity is somewhat uncertain, since through a space of 800 feet in length, no workings have been carried on, with the exception of some shallow shafts, long since filled up. A little farther, however, the ore deposits, skirting on the south the knoll, surmounted by the remarkable transported boulder of granite, called the Motto Stone, come in contact with the silicio-felspathic rock, and continue along its under side for nearly a mile. The mine of Upper Cronebane consequently presents features very different from those exhibited farther west. The principal deposit consists in a great measure of the sulphuret and the black oxide of copper, associated with soft clayey matter or "flucan," and appears in depth to pass into pyrites. The north or "lying" side of the lode is at first occupied by 6 to 10 feet of a black, smooth carbonaceous clay-slate; but is farther eastward replaced by a white argillaceous mass, containing one or two thin bands of carbonaceous matter, and occasionally rounded and isolated lumps of galena. The beds are affected by many sharp turns and twists, although their continuity is apparently unbroken; and at such points the carbonaceous shale is particularly contorted and shattered. The inclination is also subject to sudden alterations, and varies from 60° to 25°.

At the surface the outcrop of the principal deposit is marked by a strong gossan, or brecciated mass of slatey rock and brown peroxide of iron, which about the middle of the last century was found to contain native silver in very minute particles. This metal was extracted by fusion with lead and cupellation, and was proved to yield 30 grains of gold in the ounce, or 6¼ per cent.

The apparent relation of the black ore to the felspathic rock is well exhibited in the workings. Reid's shaft is sunk through a mass of this kind, yellowish white in colour, and hackley in fracture. On the west, a large development of "flucan" contained pyrites and a blueish black copper ore,—the latter being the most usual, even at the depth of 33 fathoms. About 70 fathoms farther west, the "soft white ground" ceased, and was succeeded by a dark and hard slate, in which the ore died away; and the same phenomenon was repeated in all the successive levels. Parallel deposits of ore, about 450 feet on the south, were intersected by the "Lodge level," which though analagous in position to the productive lodes of the lower mine, have been for many years neglected.

Upper Cronebane has laboured under the disadvantage of having no outlet for the subterranean water, although situated on very high ground, and its powers of production have not therefore been fairly tried. Few situations could offer a finer opportunity for the establishment of an extensive mine without the necessity of engines for raising water, and with the favourable prospect of intersecting several courses of ore, which are known to have been productive at shallow levels. If the deep adit were prolonged some 500 fathoms, it would arrive beneath the upper mine at a depth of no less than 100 fathoms; and whatever ore were thus discovered, would be extracted with a facility unusual in copper mining, whilst the important advantage of a convenient locality for "dressing" the ore would be obtained,—a process which when rudely conducted, as it must be in the present exposed position of the "floors," is fatal to an ore so specifically light as the black oxide of copper.

The working of the mines had for some years been conducted in an unskilful manner, but since they have been in the hands of the Messrs. Williams of Cornwall, much has been done in clearing and making everything secure. The levels are of dimensions consistent with the best principles of mining; and the lode is regularly worked in stopes; the "deads" thrown under foot; and thus, notwithstanding the width of some of the excavations, accidents never occur.

Stone-walling or "styllen" is used to great advantage, where the slatey rock is sufficiently hard; and in the timbering it is found that the Irish larch and Irish-grown Scotch fir (pinus

sylvestris) last remarkably well, even, as the captains of the mine assert, better than Norway timber.

The copper ores exported from Cronebane and Tigroney and sold at the Swansea ticketings, appear to have been as follows, for the last nine years :—

——	1844.	1845.	1846.	1847.	1848.	1849.	1850.	1851.	1852.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Cronbane - -	819	1,635	2,325	1,241	137	–	13	–	25
Tigroney - -	353	657	644	422	–	–	13	–	–

The machinery employed for various purposes, is as follows :—

1 undershot water-wheel of 19 ft. diameter, and 7 ft. breast, pumps from 40-fathom level.

1 undershot water-wheel of 20 ft. diameter, and 7 ft. breast, drives 10 stamp-heads.

1 overshot water-wheel of 50 ft. diameter, erected for stamping and jigging the ore.

1 overshot water-wheel of 40 ft. diameter, occasionally works the pumps.

1 overshot water-wheel of 40 ft. diameter, drives 10 stamp-heads.

1 steam-engine of 24 inches cylinder, draws at the Boundary shaft.

A more powerful steam-engine was erected some time since by Mr. Johnson, aided by a loan from the Government, for the purpose of stamping on a large scale the "burrows" or old mine heaps which had been represented to contain a useful proportion of copper. False results had however been obtained through the fraudulent conduct of the dressers, who made the experiments; and the whole scheme necessarily fell to the ground.

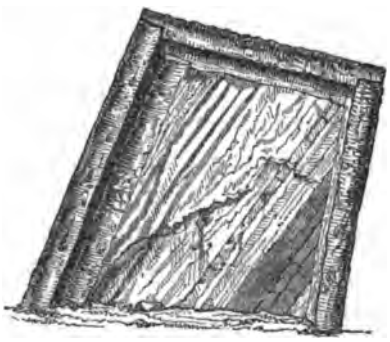
Pursuing its course to the north-eastward, the same series of metalliferous deposits has been explored in the mine of Connary for a length of 400 fathoms, and to the depth of 84 fathoms. The sulphide with black oxide of copper has also here been the predominant ore, associated with argillaceous matter or "flucan," and sometimes with portions of galena, antimony glance, and zinc blende; in certain spots, as near the Cross roads, it has

been found within 6 feet of the surface, and is generally covered by a mass of "gossan," from 6 to 10 feet in depth.

The dark ore of copper, which forms so remarkable a feature in these mines, might at first readily be taken for the black oxide alone, of which indeed those portions near the surface chiefly consist; but a closer examination shows that extremely minute crystals of copper glance, or sulphide, are agglomerated into a granular and friable substance, and are in places more or less decomposed into the oxide, The mineral occurs in strings from the finest thread to a foot and upwards in width, running parallel with the plane of the lode and the beds of the slate, and accompanied on one side by bands of iron pyrites; it has been found to a depth of upwards of 35 fathoms from the surface.

The accompanying section is taken from the 35-fathom level, near the boundary on the west, at a spot extremely valuable as well from the rich nature of the ore as from the softness of the gangue and country.

Fig. 17.



a *b* *c* *d* *e* *f*

a SOUTH OR HANGING WALL; white soft slate.
b Thick strings of black oxide of copper, interlaced with "flucan," full of interspersed pyrites and specks of black oxide.
c Irregular strings and fragmentary portions of quartz.
d Ribs of granular pyrites, with a little "flucan" or argillaceous matter.
e Eighteen inches of black shale.
f NORTH OR FOOT WALL; gray slaty rock.

There occurred near this place, some years ago, a "bunch" of ore 72 feet in width, the "flucan" of which is said to have been succeeded in depth by pyrites.

In the deeper levels the principal orey mass has been in some localities 4 fathoms wide, composed principally of iron, somewhat

intermixed with copper pyrites, and exhibiting a little black copper ore even to the depth of 70 fathoms. In the "backs" above the 60, it is divided into two, a north and a south rib, the latter of which is formed of 8 to 10 feet wide of solid iron pyrites, the central part having a cellular structure, and features more akin to those of a true vein, whilst the frequent lining of joints and cracks by a film of crystalline native copper proves that *anogenic* chemical action, or that which proceeds downwards from the surface, has been rife even to a great depth, and may have modified the appearance of ores which have withstood complete decomposition.

At the 84-fathom level, the "sulphur course" is between 8 and 10 feet wide, and still yields iron pyrites, occasionally containing portions of copper ore.

Several irregular copper lodes occur on the south, all confined to the silicio-felspathic rock, the thickness of which is nearly 700 feet, measured along the surface; one of them only has been reached by cross-cuts from the workings, and in no case was it tried for more than a few feet in length.

Near the extreme east of the workings the white massive rock, which for so great a distance has formed the "hanging wall" of the metalliferous bed, begins to appear on its northern side, and is succeeded by a narrow band of slate, so as to present the appearance of having been diagonally intersected by the lode. The relations, however, could not be duly investigated at the time the survey was on this ground, since the eastern mine, approached by the north adit, had not for a considerable period been in operation; they may, however, probably be explained by the very unequal accumulation of the felspathic rock, which is sufficiently evident on an inspection of the map.

Beyond this point no very spirited mining operations have been conducted, although the appearance of ferruginous slates, sometimes accompanied by pyrites, have led to the commencement of trials at various localities for three or four miles nearly along the same line of strike.

Connary was for some years subjected to a disgracefully bad management, by which the ore was removed without any regard to system or to future consequences, and the workings were crippled and rendered highly unsafe. Much has, however, now been improved; and if a deep adit were driven up from the

valley of Ballykean on the east, in such manner as to spare the heavy expenses of pumping, the mine would present considerable promise of future good fortune. A steam-engine of 30 inches cylinder is taxed to its utmost in keeping the water, whilst a whim-engine of 18 inches cylinder is used for the extraction; but the expense in fuel necessarily weighs heavily on the production.

Thoughout all the mines above mentioned the juxtaposition of large quantities of pyrites with clays and soft slates, combined with their exposure to air and the percolation of water, produce various decompositions, which exhibit their effects abundantly in the old workings, under the forms of blue and green vitriol, and other sulphates. The water, trickling through old excavations, continually dissolves a portion of these salts, and at its exit from the mine is carefully led into inclined troughs or "launders," in which fragments of scrap iron are laid. At the expense of the sulphate of copper, sulphate of iron is then formed, and the metallic copper is precipitated, and from time to time collected. This method of extracting a large quantity of valuable metal, which would otherwise run to waste, would appear not to have been practised in the time of Agricola, although in his laborious work on minerals, published in 1546, he frequently treats of coppery waters (aquæ æratæ), and expressly mentions the water drawn from a shaft at Schmölnitz, in Hungary, "which "erodes iron and turns it into copper," (talis in Cepusio Smolnicii aqua putealis, quæ ferrum erodit, et vertit in æs).

The same district is probably alluded to by the Cavaliere Bonardo Frattegiano, in his curious work called La Minera del Mondo, published at Venice in 1584, where, in speaking of rivers, he relates that "in the territory of Buda, in Hungary, "there is a rivulet in which, by repeatedly placing iron, it "becomes Cyprian copper."*

A process similar to the modern one was, however, described by Dr. Edward Brown, in his travels published in 1685, and in a paper in the Philosophical Transactions for 1670, when describing the mine of Herrengrund in Hungary, he relates, "There are also two springs of a vitriolat water, which turn

* "Nel territorio di Buda in Ungheria è un rivolo, nel quale ponendosi più volte il ferro, diventa rame Cipriotto."

" iron into copper, called the old and new Ziment; these springs " lie very deep in the mine, and the iron is ordinarily left in the " water fourteen days. These waters are very profitable, seeing " that the worst sort of iron, and useless old iron, is hereby " turned into the purest sort of copper, which hath this com- " mendation above other copper, to be more ductile, malleable, " and easily melted. Some will not have this to be a Transmu- " tation of one Metal into another, but that this water of the " Ziment being saturated with a *vitriolum Veneris*, and meeting " with such a body so ready to receive it as *Mars*, it deposes " *Venus*, who immediately insinuates herself so far into *Mars*, " that she doth *dividere et imperare*, and at last she substitutes " her own body and precipitates that of *Mars*."

From a letter of the Rev. William Henry, D.D., inserted in the Philosophical Transactions for 1752, we learn that the existence of copper in solution in the water flowing from Ballymurtagh had only lately been discovered by accident, but had given rise to extensive apparatus where 500 tons of iron were at the same time employed to effect the precipitation of the costlier metal. The mode of operating was very rude; pits were dug, 10 feet long, 4 wide, and 8 deep, floored with flags, and lined with stone, and the iron bars were laid on rough wooden beams fixed across from wall to wall. Dr. Henry's statement of the everlasting efficiency of the water, shows that, by him, at least, the rationale of its action was little understood. " Chains of " these pits are continued along the stream, as far as the " directors please, for the water never abates of its quality, if it " were conveyed from pit to pit through a thousand!"

By this mode a ton of the precipitate obtained from the pits yielded 16 cwt. of the finest copper.

Dr. Rutty * states, that in seven years previous to 1765 the Cronebane water had yielded 17,260*l.* from precipitate copper; the precipitate affording above half of pure metal.

Towards the close of last century, copper was obtained by the same means at Cronebane and Tigroney. According to the Journal des Mines, vol. iii., it was usual to add to the strength of the solution by placing in the water a quantity of the poor pyritous ore which had undergone a process of roasting. The

* Natural History of Dublin, 1772.

form of the pits is not described, but the ratio of pure copper to the precipitated powder was only 0·328.

The quantity of precipitate or cementation copper exported to England was, in 1788, 11½ tons; in 1789, 37 tons; in 1790, 59¾ tons.

During Mr. Weaver's management, the water was run into tanks, in which the muddy particles were allowed to subside, and then passed into pits filled with plate and scrap iron; the quantity precipitated during that series of years was 442½ tons, which sold on an average at 27*l.* 8*s.* 9*d.* per ton, being in aggregate value, 12,126*l.*; whilst the consumption of iron was rather less than one ton to the ton of the precipitate.

At the present date the water is economised at all the Ovoca mines, but by a somewhat different method; it is led through a series of narrow troughs or launders, inclined at angles of 10° or 12°, and interrupted at intervals by a deep chest or "hutch." At Tigroney the precipitate is swept down with brooms every night and morning into the hutches, the contents of which are afterwards mixed, and realize 50 to 60 per cent. of copper. The expenses of obtaining it are about 3*l.* per ton for attendance, sifting, &c. At Connary people are kept sweeping down the launders throughout the day, by which means the precipitate, although more rapidly collected, is more impure, yielding but 43 to 54 per cent. of copper.

The mode of treating the cupriferous water in Hungary, as I have seen it practised at the interesting mine of Herrengrund, near Neusohl, the same as described by Brown in 1670, is to run it through an inclined trough of about 100 fathoms in length, throughout which boards are placed in such manner as to form a succession of steps, the floor of each inclining a little backward, and on these steps are placed fragments of scrap iron, which are left undisturbed for a period varying from a week to a month, and are then coated with a precipitate of such purity as to produce 70 to 90 per cent. of metal. It remains, however, to be proved by experience at what angle the "launders" should most advantageously be inclined, and how far the more rapid collection of the precipitate may make amends for its inferior quality when frequently swept, as at Tigroney and Connary.

With respect to the early history of the mines of the Ovoca, we may rest satisfied that whatever can be gleaned on the

subject has been collected by the labours of Colonel Vallancey, and we need therefore only cast a retrospect over their condition in the last century, whence it is possible that some hint may be obtained applicable to some of the uncertain ground on the east bank of the river.*

Dr. Henry stated in 1752 that the mine of Ballymurtagh had been for some years "disused," although before that time it had yielded great profits. Cronebane, on the other hand, employed 500 men, and some of the shafts had already been sunk from 50 to 70 fathoms in depth. It would appear that the shallower workings yielded lead and silver ores, as was more recently the case on the eastern prolongation of the beds. "In sinking the "shafts, the first mineral met with is an ironstone. Beneath "this, they arrive at a lead ore, which seems mixed with clay, "yet yields a large quantity of lead and some silver. Under "this lies a rich rocky silver ore, which sparkles brightly, and "yields 75 ounces of pure silver out of a ton of ore, besides a "great quantity of fine lead."

In the third volume of the Journal des Mines, published in 1794-5, it is stated that the Ovoca mines had been in continual

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* In connexion with the history of the ancient workings at Cronebane, I may advert to a remarkable spot to which I was guided by Captain Reid. On the east of the engine shaft, the level, 20 fathoms under the surface, has been driven into a conglomerate of slate, pyrites, quartz pebbles, and granite boulders, slightly cemented by argillaceous matter; the same substance had been seen 4 fathoms deeper, and was penetrated several fathoms in length, being sufficiently consolidated to hold together for some time without timbering. This appearance of rounded masses of granite, occurring at a depth of 140 feet from the surface, had astonished the agents of the mine, who were indisposed to consider that old workings had been filled up with those materials, because no tradition of excavations in this part of the mine was known; and again, because fragments of good copper pyrites are met with amid the mass, which they supposed would not have been neglected by the miner. Looking, however, at the recent date of the utilisation of copper pyrites in our islands, and the probability of deep open workings having been carried on at a very early period, I cannot but think their objections are without foundation, and that the boulders and other fragments have been filled in, either purposely, or by one of those "runs" so likely to occur during the excavation of wide spaces.

This, at all events, appears an easier hypothesis than that of a vein-chasm having stood open at the time of the spread of the boulder-drift.

operation since 1757; and that after 1787 they had been divided into two sets, comprising respectively those situated to the west and those to the east of the river. They are described as established on several veins, the chief of which runs from E.N.E. to W.S.W., with a width of from 6 to 10 fathoms, and generally divided into three ribs; the most remarkable of the secondary veins is, first, the "Magpie," running N.W. and S.E., 4 to 8 feet wide, and producing copper pyrites and also native copper in quartz; secondly, the "yellow ore vein," coursing from E.S.E. to W.N.W., varying from 18 to 20 inches in width, and affording copper pyrites in a gangue of quartz and killas; the third is the "copse north vein," which runs N. and S., is 8 to 24 inches wide, and contains the same minerals as the last; fourth, the "copse south vein," with a width of 18 to 36 inches, and similar ores. The two latter are supposed to form a junction with the principal lode on the S.W., where it was found to be accompanied by a parallel vein which appeared to be on the line of their prolongation.

Five adit levels had been driven at Cronebane, the deepest of which was opened in 1791; and several shafts had been sunk, although the deepest was not more than 36 fathoms.

At Connary, near the main road, the vein contained, at a short distance from the surface, a steel-grained galena, averaging about 25 per cent. of lead, and 1½ ounces of silver in the cwt. The gossan of the lode presented an ochrey substance, producing one half per cent. of silver and a little gold.

The massive yellow copper ore gave 5 or 6 per cent. of copper, and the pyritous ore from 1 to 10 per cent. From the latter, when smelted at Liverpool, a certain proportion of silver was extracted by liquation, which yielded 0·01146 of gold.

The quantities of ore raised between May 1788 and May 1791 were as follows:—

	1788.	1789.	1790.	Average produce of copper.
	Tons.	Tons.	Tons.	
Yellow copper ore -	116	262	563	8 per cent.
Pyritous ore - -	52	473¼	112¾	5 „
Roasted ore - -	24	22½	47½	9 „

The author of the notice was unable to obtain an account of the quantities raised at Ballymurtagh, a mine which had been worked long previous to Cronebane.

Mr. Weaver's description of these mines in his Memoir on the Geological Relations of the East of Ireland is well known. During the 24 years for which he was connected with Tigroney and Cronebane, the production of those mines was as follows:—

	Copper ore.		Copper.		Average produce.
	Tons.	Cwts.	Tons.	Cwts.	
In 12 years ending 1799 - -	7,533	0	670	11	$8\frac{14}{15}$
In 12 years ending 1811 - -	19,342	13	1,046	10	$5\frac{5}{12}$
Total - -	26,875	13	1,717	1	$6\frac{13}{33}$

At that time sulphur was extracted on the spot from the copper pyrites, by a process of distillation conducted in kilns containing 50 or 60 tons of ore, and fitted with close flues leading to a long brick receiver; the sulphate of copper formed during the decomposition being afterwards dissolved out and treated by cementation.

In 1840, and the two subsequent years, the interruption of the sulphur trade with Sicily obliged the English manufacturers to turn their attention to the iron pyrites of the Ovoca mines, an ore which from its granular texture admits of easy metallurgical treatment, although from its general impurity, and from the frequent presence of arsenical pyrites it is disadvantageously employed for particular purposes. Some attempts have been made to economize it on the spot, but have not hitherto given satisfaction, and although large quantities of the ore are still exported to England, almost the whole of it is applied to the production of sulphuric acid. For a year or two during which an active demand existed, a very great amount was exported from the Wicklow mines;* and although the fluctuation of price has rendered it sometimes scarcely worth while to con-

* In May 1840, Ballymurtagh was raising 1,200 tons, Ballygahan 150 to 200 tons, Cronebane and Tigroney 600 to 700 tons, and Connary 200 to 300 tons per month, or about 2,400 tons together.

tinue the workings, particularly in such portions of the veins as produce the more impure and therefore low-priced ore, the annual amount raised has of late been greatly increasing.*

The importance of the produce of the Ovoca mines will best be appreciated from the following return, communicated by the Custom House authorities of Dublin, of the quantities of iron-pyrites (sulphur ore) and of copper ore, shipped at the ports of Wicklow and Arklow in each year from 1840 to 1852, both inclusive:—

Years.	Iron pyrites.			Copper ore.			Grand total of both ores.
	Wicklow.	Arklow.	Total.	Wicklow.	Arklow.	Total.	
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1840	27,172	13,004	40,176	7,065	4,365	11,429	51,605
1841	40,823	36,565	77,388	1,764	3,376	5,140	82,528
1842	20,494	19,963	40,457	5,406	5,776	11,182	51,639
1843	19,995	19,191	39,186	4,292	4,545	8,837	48,023
1844	15,772	19,189	34,961	4,892	5,270	10,162	45,123
1845	9,573	29,445	39,018	4,854	5,042	9,896	48,914
1846	10,815	25,245	36,060	3,958	4,350	8,308	44,368
1847	10,619	29,889	40,508	1,919	2,886	4,805	45,313
1848	15,462	25,777	41,239	307	3,600	3,907	45,146
1849	19,103	26,524	45,627	142	3,800	3,942	49,569
1850	24,221	49,823	74,044	1,493	2,836	4,329	78,373
1851	29,399	73,039	102,438	41	2,023	2,064	104,502
1852	30,770	67,218	97,988	444	2,358	2,802	100,790
Totals	274,218	434,872	709,090	36,577	50,226	86,803	795,893

21 cwts. are allowed to each ton of ore.

* It may here be remarked that a large proportion of pyrites is left unworked, in consequence of its being too much mingled with other substances to be available by the processes at present employed. The small quantity of sulphur (as such) which can readily be extracted from the ore is evident on the following consideration: an average pile of the sulphur ore may contain about 75 per cent. of pure iron pyrites, and from 100 tons of ore we shall therefore only have 75 tons of useful mineral. But iron pyrites is a bisulphuret of iron, or contains two equivalents of sulphur combined with one equivalent of iron; and when it is heated to redness in a close vessel it gives off, not the whole of its sulphur, but less than half; and the remainder enters into a new combination with iron, called magnetic pyrites, and represented by the chemical formula $\dot{\dot{F}}e + 6\,\dot{F}e$.

Casting a retrospective glance over the remarkable series of ore-deposits detailed above, we observe that the metalliferous contents are disposed in several groups of straight lines presenting, with a singular degree of parallelism, most of the characteristics of bedded or stratified masses, such as their conformability to the beds of the slatey rock of the country, their freedom from vein-stone, from "vugs," and from crystallized minerals, their laminated structure, and the gradual blending, in most cases, of their ores with the adjoining strata. Yet the mode in which, when closely followed, they appear to cut *across the strike* of certain beds, and the existence of such phenomena as the "heave" described in Ballygahan mine, on the west of the engine shaft, the T-shaped fissures in Tigroney, and lastly, a comparison of these with the facts disclosed in the mines of the Paris mountain in Anglesey, induce the belief that they must be regarded as lodes or true metalliferous veins of a peculiar order. The copper lodes, lying, as will be remembered, on the south of the "sulphur course," monopolize all the characters here cited, and we might be led to the conclusion that they alone are to be viewed in this light, were it not a too improbable assumption, that they should have made their appearance in lines so nearly coinciding with previous sedimentary deposits of pyrites, which both in mode of occurrence and in mineral contents are in places almost undistinguishable from them; and hence we are necessitated to apply to all the same attempts at explanation.

Under such circumstances it is not uninteresting to take these features, and adding to them the characters of the slatey, the hornblendic, and the felspathic rocks of this zone of country, as well as the association of certain minerals found together, to compare these veins with some of the irregular ore deposits (Lager Germ., Amas aplatis Fr.) which occur on the continent of Europe. At Berggieshübel in Saxony, deposits of this order, containing magnetic iron, copper ores, zinc blende, galena, with garnet, quartz, &c., follow very regularly the strike and dip of

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Thus the 75 tons above mentioned, containing 53·3 per cent. of sulphur, and giving off less than half of that amount, would yield only about 17 tons of actual sulphur, though the rest may be obtained from the magnetic pyrites by the process of burning, in which it unites with oxygen, and forms sulphurous acid.

the environing clay-slates, the latter varying from 15° to 90° to the north-east. Near the surface were found in place of the above, red and brown ores of iron, with barytes.

But more remarkable, from the large quantities of ore extracted from them, and the long period during which they have been wrought, are some of the orey masses of Scandinavia. At Arendal the "country" consists of gneiss, passing occasionally to hornblende or to mica slate; and a number of more or less parallel bed-like masses run throughout a narrow zone, but for some 12 miles in length, parallel to the lamination of those rocks. The minerals which they present are chiefly magnetic iron, associated with hornblende, granular augite, garnets, epidote, &c., and occur in a kind of vein with a thickness of from 6 to 60 feet, without any distinct wall to separate it from the rock, and often of a laminated structure corresponding to that of the gneiss.

At the mines of Dannemora, celebrated for the excellent quality of the iron produced from its magnetic ore, analogous features are again presented: that ore is associated intimately with chlorite, and more or less with pyrites, zinc blende, galena, quartz, garnet, hornblende, &c., the deposit being bounded in some parts by a gray limestone, and in part by a porphyritic rock of silicious felspar, or petrosilex, locally termed *hälleflinta*, not unlike the above-mentioned masses which occur near the lodes of the Ovoca.

Fahlun, during five centuries the source of vast quantities of copper, is a deposit of very similar character, situated in a gneiss country, but divided from that rock by a zone of mica-slate and strips of very contorted talcose-slates. The copper pyrites, which is the chief object of the exploitation, is accompanied by magnetic iron ore, iron pyrites, zinc blende, galena, quartz, and chlorite, the metallic sulphides containing a small proportion of silver and gold. Although in form this metalliferous mass differs more than any of the above from the pyrites lodes of Wicklow, and has been worked down to a depth of 200 fathoms without presenting any of the characters of a lode, it is crossed by a great number of true metalliferous veins of small dimensions, bearing copper pyrites almost free from admixture with iron pyrites, and somewhat akin, it would seem, to the copper lodes described in Ballygahan and Tigroney mines.

We may thus note a certain degree of affinity between the localities described in this paper and the beds and masses of analogous ores occurring in the gneiss and ancient slates of Sweden. We have not in Ireland, it is true, that variety of silicate minerals, nor the combinations of cerium and other rare metals which characterize the Scandinavian deposits, but the association of copper pyrites with magnetic iron, with chlorite, and large masses of iron pyrites, cannot but suggest a comparison which tends to raise our expectation of the future prospects of the Wicklow mines.

Whilst observing the subject in this light, it may not be overlooked that the upper part of the beds explored by the miner at Ballymurtagh varies materially from that at Cronebane and Connary; at the former, the principal deposit, iron pyrites, occurs immediately beneath the gossan, whilst at the latter the following remarkable sequence of ores presents itself:—

Surface, gossan	-	Brown iron ore with a little silver, 8 feet thick.
18 fathoms 25 „	}	Black copper ore, with occasional portions of galena, zinc blende, and antimony glance.
35 „	-	Copper glance, with black copper ore.
45 „ 84 „	{	Iron pyrites, with occasional ribs of copper pyrites, below which the example of Ballymurtagh would lead us to expect copper pyrites.

The difference thus observed results, no doubt, in a great measure, from the western bank of the Ovoca, exhibiting a deeper part of the metalliferous plane, which at an epoch posterior to its solidifaction has been so affected by dislocation and denudation, as to present that deeper part almost at the same level with the higher part on the eastern bank of the river.

In the plate (III.) let the line N K O represent the intersection of the surface of the ground by the metalliferous vein at a period before the disturbances which caused the heave, and let E F G H be a part of the plane of dislocation, which we have above described as now separating the extremities of the lodes by about 1,000 feet:* the line of intersection of the two planes,

* The total amount of heave may probably be due to several distinct dislocations; but, since the result is the same, we may, to simplify the subject, take their sum and consider them as one major dislocation.

i. e., of the lode and the dislocator, before any change of position has taken place, will be K G. But the heave has been effected by the depression of the whole mass K O D G, in consequence of which the point K of the lode has slipped down to a point M, and the intersection of the eastern part of the lode with the dislocation is M H, leaving the horizontal distance G H, or at the surface L M, between the severed portions. Since the epoch of disturbance the portion N K A L has been abraded, and A L the modern surface along the line of outcrop, although at considerable depth below the original "back" of the lode, nearly corresponds in elevation with the surface M C, the upper portions of which are evidently much more nearly the upper part of the metalliferous deposit as it originally existed.

In the figure the outcrop of the main vein is represented by a double line, its position and that of the copper lodes in the transverse section C D by dotted bands. The principal shafts and galleries of the mines are also represented, the number which is attached to some of the galleries showing the depth in fathoms below the adit level. The workings of Ballygahan mine are given in dotted lines, as supposed to be seen *through* the cross course or dislocating plane. A part of the workings thus shown are upon the pyrites course, and a part on the copper lodes, whilst most of the shafts are sunk perpendicularly through the slaty rock, intersecting the orey deposits only at certain points. These minutiæ can, of course, only be represented by a plan and section on a larger scale, such as that to which I have before referred. The object of the diagram is simply to show, first, how a large horizontal displacement is probably the effect of a more or less vertical depression of one division of the rock mass with regard to the other; and secondly, how the eastern division, remarkable in its upper part for a collocation of minerals peculiar in itself, and differing from anything on the western side of the river, is much nearer than the latter to the pristine surface of the land. The shafts and levels are introduced as guides to the locality, and as showing the depth and horizontal extent through which the excavations have been carried on within the particular district referred to.

It will readily be perceived, when we observe the considerable tract of ground offering indications of ore, but lying as yet

unwrought, that any ray of light brought to bear on the illustration of this succession of different minerals at increasing depth, may involve consequences of the highest interest and importance in a commercial point of view. The mines which we have described as in active operation occupy a length of little more than 2 miles,* whilst there remains on the S.W., between Ballymurtagh and the granitic rocks of the mountain mass of Croghan Kinshela, a space of above five miles in length, throughout which the same or analogous deposits of ore have been proved to exist at intervals. As adverted to in p. 371, appearances of considerable promise have been met with at Ballymoneen, Knocknamohill, Ballycoog, and Moneyteige; the two latter being in the Carysfort royalty, and adjoining Croghan. From various causes no efficient exploration has yet been made in these setts; and it still remains to be proved, whether, as in the Ovoca mines, vast masses of iron pyrites will be found beneath the more mixed ores which occupy the surface, a conclusion very probable, but rendered uncertain by the varying character of the adjacent slate work.

We have seen on how large a scale the pyrites is now exported from the mines of Ovoca, and cannot doubt that at the rate of 100,000 tons a year this extraction must go far toward exhausting their stores at no distant period. How important, even in these days of peace, are such supplies of "sulphur ore" to our great manufactures; and how would that importance be increased should our intercourse with Sicily be interrupted by war or other causes! Evident enough it is, that these peculiar riches of the Wicklow Hills have become almost indispensable alike to English and to Irish industry; to the one, in their application, and to the other, in their extraction; and that for the continuance of a bond so desirable, and a boon so mutually useful, further efforts on the part of the geologist and miner will be needed, which will merit an extended, nay, even a national interest.

At a few other spots in the county of Wicklow the slaty rocks contain small quantities of metallic minerals: thus, on the right-hand of the road, between Ballinglen and Sandyford, large masses of gossan mark the presence of a lode from which

* See the Map of the district, Pl. II., appended to this Memoir.

lead ore was raised about a century since, but the cultivation of all the land around it, and the filling of the shafts, render it impossible to trace its course. At Ballinalea, on the high road from Rathdrum to Dublin, a little copper pyrites has been seen in a powerful lode of quartz, which contains numerous rhombohedral cavities, partly occupied by brown peroxide of iron, and may therefore probably be due to the decomposition of carbonate of iron. A shaft of inconsiderable depth was sunk at this spot, but without success.

At Ballintemple, near the spot where the pyrites veins cross the valley of the Aughrim river, and on the south side of the stream, a small lode of lead ore courses nearly at right angles to the strike of the slate beds, and in the small workings which have been opened upon it has exhibited here and there a rib of galena, varying from 1 to 8 inches in width, accompanied by *flucan* or soft argillaceous matter. In a neighbouring valley in Clonwilliam a lead lode has also been seen, but not hitherto opened on.

Proceeding southward into the county of Wexford we find that very few localities have presented favourable indications of the presence of metallic minerals. A few years since, however, a mine of considerable promise was opened at Caime, a short distance to the west of the town of Enniscorthy. The dark grey clay slate of the country, in its usual strike of N.E. and S.W., is pierced by a nearly vertical lode, coursing 15° south of east, and splitting on the west into two branches. The upper portions of the lode yielded a few tons of copper ore, but argentiferous galena was the chief product of the mine, and the point of juncture of the two branch veins above-mentioned was enriched by an accumulation of galena, of some 12 feet in width, down to the 47 fathom level, but dwindling away thence to the 67 fathom level, where it was not more than 5 feet wide.

From this rich deposit the veins run to no great ascertained distance, with a width of about 3 feet, a small part of which only consists of ore, the rest being composed principally of threads of quartz. The general character of the veins or "strings," which vary from $\frac{1}{10}$ of an inch to 3 or 4 inches in width exhibits a riband structure, the outer members or plates (those attached to the walls) being sparry iron, and the inner, galena or zinc-blende, or both together: thus,

Sparry iron,
Galena and zinc-blende,
Sparry iron.

Calcareous spar often occurs with the sparry iron, and the decomposition of the zinc blende, which is sometimes mixed with it in exceedingly minute particles, tinges the exterior of all the fragments on the surface with a dark brown stain.

The dressed ore contained about 75 per cent. of lead, and 15 ounces of silver to the ton of lead.

A little carbonate of lead is seen in the fragments from the upper part of the lode.

This mine is situated at a considerable distance from all surface evidence of massive or igneous rock, being nearly 4 miles to the E. of the granite, and 3 miles W. of the bands of greenstone which strike across the country from the river Suir on the S.W. to near Gorey on the N.E. One of its most remarkable features is the irregularity of its course and angle of inclination, which gave to the workings, although they were of no very great extent, a most complicated appearance. Thus, from the 37 fathom level the vein dropped perpendicularly to the 47, and was then 30 feet wide, worked in one excavation.

The operations were checked on the W. by a *slide* or dislocating plane, which holds water up to the surface, and beyond which it is very probable that the lodes may yet be found. In 1846 the mine had for some time been abandoned, and a large opencast or pit was all that remained to be seen; it was full of water, and had been excavated in this manner in consequence of the confused occurrence of strings of ore amid old workings.

More remarkable in many respects is the Barristown lead mine, in the extreme S. of Wexford, a place worked evidently at a very early period; even according to the common traditions of the country, by the Danes. The lode had been followed only 12 fathoms deep; and since on examination a few years ago, it was found that ore was visible at that depth, it was assumed that the old miners had been baffled by water, although it afterwards proved that the total interruption of the lode by a "slide" had been the cause of its abandonment.

The mine, which had been for a few years past idle, was about 1846 attracting considerable attention, from the un-

usually large proportion of silver, 60 to 70 ounces of silver per ton of lead, contained in its ores. In a geological and mining point of view it is also interesting from its low angle of inclination, and the peculiar heaves by which the northern or principal of the three lodes is frequently dislocated.

The clay slate of the neighbourhood dips at an angle of 45° S. by E. and S.S.E., whilst the vein courses about E.S.E. and W.N.W. with an inclination to the north, which is very variable, although averaging 40° to 50°. It is generally about 3 feet wide, and composed principally of ribs of quartz with sparry iron ore, galena, and zinc blende, the sparry iron adhering to the walls or sides, and often crystallized towards the interior, whilst the other ores occupy the central part. Parallel in strike, but dipping oppositely to the lode, are several slides or faults, generally accompanied by an inch or two of *flucan* or soft clay, which dislocate the lode, and that too, it would appear, always in an opposite direction from what it would be expected, according to the law which commonly holds good in such cases.

Thus, in the old shallow workings east of the "footway shaft" the lode dips at the low angle of 22° N.E. by N., whilst the slide falls nearly opposite to it at 25° to 40° W., and the lode is heaved 6 or 8 feet on the side of the *acute angle*, whilst it would ordinarily be looked for on the side of the obtuse angle formed between the intersecting planes. Phenomena of a similar character are seen also in the "Danes' Shaft," close below the 18 fathom level, on the west of the "Flat-rod Shaft," and elsewhere; whilst after the lode in its descent has several times been thus dislocated reversely, it abuts at last against the face of a set of beds of black slate-rock, which appear to act a very similar part to the "slides," with the exception that no farther trace of the lode has yet been met with.

Since examining these heaves underground, I have had to regret that no detailed section of the mine at that time existed, and that I was, by the early abandonment of the mine, disappointed in the expectation of examining them more minutely on a future visit; it thus becomes impossible closely to inquire into the nature of a phenomenon, highly interesting both to the miner and the ge logist, and I must rest contented with pointing out that there exists in the Barristown mine a succession

of reversed faults similar to those which we occasionally observe in coal measures, and to those on a small scale described by Messrs. Prestwich and Morris, Quart. Geol. Geol. Soc. vol. ii. p. 402, and by Mr. De la Condamine, in the same work, vol. viii. p. 193.

In 1846 a steam-engine, with cylinder of 30 inches diameter, was employed to pump at the principal shaft to a depth of 30 fathoms, and to work horizontal rods in the western shafts to 18 fathoms, besides driving a crushing-machine for the dressing of the ores.

Stream Works or Alluvial Deposits.

From time immemorial, ornaments and insignia of solid gold have been found in Ireland, and men have wondered whence came so great an abundance of the most precious metals among the early inhabitants of the country. That it could have been picked up from amid the sand, gravel, and clay of the beds of streams and the adjoining alluvial cover, was a supposition that seems to have met with but few supporters; yet incredulity was forced into belief, when sources of this kind suddenly yielded a supply of gold in the county of Wicklow at the close of the last century; and now at length the astounding successive discoveries of auriferous detritus in Siberia, California, and Australia, have rendered that mode of occurrence familiar to us all.

It is, however, in no small degree remarkable how previous experiences are gradually forgotten, analogous histories neglected, and a great cry of novelty raised upon a phenomenon of an order which ought to have been well and generally known. Whilst tongue and press during the last five years reiterated expressions of astonishment that gold should be found in lumps near the surface of the earth, the recent scenes in Wicklow were overlooked, and the almost universality of the occurrence of alluvial gold appears to have been lost from sight by all but a few geologists and miners. This is no place for entering at large into the question, but it may be noted, that a large portion of the gold current among the ancients was derived, according to the testimony of various historians and geographers, from such sources. The author of the Book of Job, clearly alluding to auriferous sands, mentions "that the earth

has dust of gold:" and Herodotus, Athenæus, Strabo, and Pliny, all bear evidence of the wide diffusion of the metal under the same circumstances.

In fact, we can scarcely point to any regions watered by streams flowing from primary mountains in which more or less gold has not been, or is not even yet to be, found. Witness, as a few known examples, our Cornish stream-works, Lead Hills in Scotland, the valleys of the Rhine, Danube, Drave, Nile, and numerous rivers in Bohemia, Transylvania, and Spain, from many of which gold is still obtained in small quantities by the streaming processes. But in all the old and well known countries, the simple operation of picking out the richer portions of these deposits was commenced thousands of years ago, and very few spots are left rich enough to reward the labour of the seeker; it is therefore, in a general way, only in lands new to civilization, and where the existence of gold has been from particular circumstances undiscovered by the natives, that those great supplies can be expected, which of late have given so great an impetus to communication and commerce.

In the year 1795 it transpired that lumps of pure gold had been picked up in a valley on the flank of the mountain called Croghan Kinshela, in the southern part of the county of Wicklow. The discovery, which was purely accidental, was kept a secret for some months, but no sooner was it made known than crowds of the country people, throwing aside their ordinary occupations, rushed to the spot to secure a share in so promising a harvest. Some hundreds of gold-diggers (to adopt the new-world phrase) were soon employed along the stream, and during about six weeks appropriated to themselves a considerable amount of pickings. After that time the Government, fortified by a special Act of Parliament, established a more systematic *streaming*, under the direction of Messrs. Mills, King, and Weaver, and up to the outbreak of the rebellion in May 1798, continued to make the operations remunerative. During that unfortunate period the works were totally destroyed, and not till the year 1801 were they again brought into activity. It was now that the directors, reasoning on the evidence obtained in various countries, that alluvial gold has been derived from veins of that metal situated at no great distance up the stream, commenced the driving of a level or gallery into

Croghan, and the cutting of a long series of trenches in various directions, from the surface down to the solid rock, for the purpose of discovering the lodes, from which it was argued that the gold had travelled. The reasons for carrying out these operations are fully given in the detailed paper above alluded to, by Mr. Weaver, in the Transactions of the Geological Society of London. But the level was carried for a great distance (about 178 fathoms) into the heart of the mountain, and the costeaning trenches were dug for thousands of fathoms in length, yet not a particle of gold in situ ever rewarded this patient labour. Veins of quartz, numerous yet irregular, were indeed discovered, but they appear to have been almost totally destitute of metallic contents.

Meanwhile the stream-works, or operations in the alluvial deposit, were perseveringly continued for some years, but the "crop" or best part had already been picked by the country people, and after a while the Government was advised to abandon the undertaking, having raised above 944 ounces of gold, the ingots of which were from $21\frac{3}{8}$ to $21\frac{7}{8}$ carats fine, the alloy being silver, and the total value at the time being 3,675*l.*

Since that period it has been attempted to work the same deposits by a company, but without success, partly, it may be presumed, from the rarity of the precious metal, and partly from the difficulty experienced in all gold-streaming or gold-digging regions of obtaining from the workmen the full produce of their labours. There appears to be a something so magical in the sight and feel of native gold,—so dangerous a property of ready convertibility into all the requisites of life, that in passing through the hands of a labourer it cannot be a matter of surprise that the more tangible pieces stick by the way, and are not forthcoming among the assets of the company. I have heard in Transylvania striking anecdotes of the demoralization produced among paid workmen by the handling of the precious metals in a state requiring little or no farther operation for adapting them to pass current; very similar accounts have reached us from South America; and it remains to be seen whether companies formed for the working of stream-gold in Australia will be successful in securing their expected profits.

Of late years, only a few of the neighbouring peasants have from time to time been engaged in gold-washing, and it is very

difficult to form a fair estimate of the remuneration yielded them by their labour.

The more important of the auriferous localities are situated in the valleys which branch off from the northern side of Croghan Kinshela, and through which the waters flow to the Daragh or Aughrim river. Two of these streams unite at a point not far from the well-known Wooden Bridge, and form the so-called Gold mines river. The vestiges of the gold-washers are recognized in the confused heaps of stone, many of them overgrown with sod, which occur scattered along the bank of the streams. The sides of the hills, well-clothed with wood and grass as you ascend from the Wooden Bridge, fall more steeply to the stream, and present a wilder aspect on a nearer approach to Croghan. The clay slate-rock of the country is, however, seen only occasionally, except in the bed of the brook, where, in the cavities amongst its rough, up-turned, and broken edges, many of the pepites or nuggets of gold were found. Higher up the valley a considerable cover of detritus overlies the solid rock, attaining in some places a thickness of 50 feet, and increases to a great extent the difficulty of working with advantage; since the precious metal was only found in a thin bed at the bottom of this mass of useless sand and soil. As usual with such deposits of local detritus, its variation in thickness was very great even in a limited area; and thus, just as the Siberian, Californian, or Australian gold-digger may expect, the treasure was in some places to be attained close to the surface, in others only beneath a great thickness of valueless material more or less difficult to pierce through and remove.

The gold occurred disseminated throughout an irregular bed composed of clay, sand, and fragments of rock more or less rounded; the particles were generally minute scales, but large solid lumps were found from time to time, the heaviest of which weighed 22 ounces. A great number of other minerals accompanied the gold, and were described by Mr. Weaver after a careful examination of the concentrated sand; among them magnetic iron ore, sometimes in masses of half a hundredweight, was the most frequent, titaniferous iron, specular, red, and brown iron ores, iron pyrites, tin ore, and its curious associate wolfram, a manganese ore, garnets, quartz, and chlorite were also abundant. Some of the specimens exhibited the gold in

association with wolfram, brown iron ore, and with quartz. To the above list Mr. Mallet has added (Tran. Geol. Soc., Dublin, Vol. iv., p. 271,) several others from his own observation; at the head of the new species stands platinum, and then succeed the ores, galena, copper pyrites, and molybdenite, and the gems sapphire, topaz, zircon, and spinelle.

It is very interesting to trace this association of substances which have been found together in all the gold-fields of the earth wherever they have been accurately described. Dufrénoy has published in the *Annales des Mines* the results of his examination of concentrated sands from California and New Granada, and compared them with the products of the Uralian washings, and of our tin stream-works in Cornwall. In these and many other places which might be referred to, magnetic iron is the principal ingredient, in the Ural 23 per cent., in California 59 per cent.: titaniferous iron sand is also present in large proportion, and in all of them more or less of the same gems have been discovered. Some of the more frequent, next to the varieties of quartz, are sapphire, zircon, spinel, and garnets. The American sands—both of California and New Granada—contain the largest proportion of white zircon, whilst in the Ural it is surpassed by chrysoberyll of a yellowish green colour, and chatoyant play of light, forming as much as 10 per cent. of the entire body of the concentrated sand. Spinelle has not been observed in either of these, although common in the tin-streams of Cornwall and of Pyriac in France.

The most important companion of the gold is, however, according to Mr. Mallet, the tin-stone; and from having been able to detect but little of it on the spot, I was much surprised at the announcement that he had obtained 3½ lbs. of stream-tin from about 150 lbs. of the sand, a ratio of productiveness which throws into the shade all the richest stream-works ever found in Cornwall or on the continent. Could it only be proved to be distributed in the same quantity over any considerable area, the gold valleys might again become tenanted to good purpose, and it would then be very strange if some clue were not obtained to the original depositories of this valuable ore, hitherto sought for without the least success.

Having been desirous (at the time these sheets are passing

through the press) of ascertaining from Mr. Weaver whether he had ever found the tin-ore in a sufficient ratio to render it worth extraction, and also whether any approximate percentage had been calculated for the gold in relation to the total of the material washed, he was good enough to give me all the particulars obtained, from which it appeared that at the time of the activity of the works no sufficient quantity of tin-ore was procurable to render it economically valuable, and that from the great variation no satisfactory estimate was made of the quantity of material from which a unit of gold was obtainable. With respect to the occurrence of tin-stone, he has to complain with reason, that after his repeatedly placing on record that it had been recognized and proved by him, the subject has been brought forward as a new one, and disputed or said to be established, by inquirers to whom the previous observations ought to have been thoroughly known. And here I cannot but express the pleasure which I felt in observing the spirit and interest with which so aged a veteran entered into the subject, and discussed it for hours. Mr. Weaver was a hearer of the great Werner at Freiberg in the year 1790, and a fellow-student with an illustrious trio, of whom one only now remains to us, Von Humboldt, Von Buch, and Freiesleben, late the chief officer of the Saxon mines. The desirable "mens sana in corpore sano," strengthened by a cultivated taste for scientific inquiry, and by a life of useful activity, has distinguished these patriarchs of geological science even when they have thus passed their eightieth year.

Besides the principal auriferous valleys on the north side of Croghan, several others have been closely examined, and some of them were found to yield gold; in Coolbawn a piece weighing 2½ ounces was discovered, and a little glen which intersects Ballintemple has been lately worked on a small scale with some success for several years. The same minerals, which I have above enumerated, were generally associated, and it is not without interest to observe that many of them are identical with those exhibited in the lodes at Ballycoog and Moneyteige, as described above,* and, moreover, that from the form of the hills it would be very possible to derive the spread of the auriferous drift from that strongly marked ridge. Indeed, I am inclined

* Page 371.

to infer that it was the back or upper part of these lodes, the waste of which furnished the greater part of the alluvial metallic substances found in the valleys below,—and amongst them of the gold. Not only is this opinion supported by the presence in the lodes of so many of the same minerals, but by the very generally observed phenomenon of the upper part of lodes being much richer in gold than the deeper portions, whilst it is well known to the miner, that after an auriferous alluvium has in many cases been followed up to what appears without doubt to be its parent vein, only minute traces—or perhaps none at all—have been discovered in that part of the original deposit to which the entire surface has now by natural causes been ground down.

Gold has been found also in a totally distinct locality, about 7 miles from the above, at the foot of a mountain called Croghan Moira, whose conical form attracts the eye of the geologist or the sketcher from a great distance. On the eastern side at Ballycreen, and on the western, at Ballynacapogue, small quantities only were found, associated again with many of the same minerals.

Speculations have been raised as to whether the auriferous alluvium is distributed over a large area in the country. It is tolerably clear that it was not brought into its present position by the now existing rivulets, but still it was evidently placed there after the surface of the land had acquired something like its present outline. It therefore seems to follow that the same rule which has been observed in the gulleys of Australia will also hold good in Wicklow, viz. that the drift and gold are both most abundant at or near the course of the stream, and become thinner and poorer as they ascend towards the flank of the hills; hence it would not appear probable that any large deposits exist in Wicklow, although there may possibly be many glens and valleys where some small proportion of the precious metal lies as yet undisturbed.

With the technical processes of streaming we have here no concern, since none but the simplest and most obvious have yet been employed in this district; and unless vast quantities of the material to be washed could be brought into play, it would not be feasible to employ such machines as those used in Siberia, by which sands are treated, so poor that they contain only *one millionth* part of gold.

In conclusion, let me remind the reader that only a few facts in the geology of Wicklow have been adverted to in the foregoing pages. Fully to appreciate the bearing and relation of the numerous questions which suggest themselves in any particular area, the examination of a large region must first be undertaken by the investigator; and any opinion on theoretical points, which is founded on a partial survey, must remain open to the corrections of a more widely extended knowledge. The miner has to deal, however, chiefly with one department of geology, the *geognostical* character and position of the rocks,—with their actual condition, in fact, as they now exist. It is only in a secondary degree,—although sometimes in matters of high importance, that he need to occupy himself with the study of the relative age of deposits or eruptions. For this reason, an isolated memoir like the above may always be serviceable in recording observed facts, whose truth is independent of some of those considerations with respect to geological antiquity which interest, probably, the larger class of readers, but which necessitate the comparison of observations collected from a very extensive province.

The maps appended to the memoir, drawn on the scale of an inch to the mile, and coloured geologically, will serve to illustrate much of what has been described among the general features of the Wicklow mining districts. It has been thought the more desirable to add them, since both of the tracts represented, although differing from one another *toto cœlo*, offer very numerous points for examination and study within an area at the same time moderate in extent and accessible.

Plate I. includes almost the whole of the lodes described in the first part of the paper, with many of the granite viens mentioned at p. 351, and also the interesting appearances at the junction of the granite and mica-slate, which have been commented on by Sir H. De la Beche in his "Geological Observer."* It is, moreover, a district which, although very laborious to examine in detail, as may be inferred from the inserted heights above the sea level, possesses additional inducements in the succession of striking scenes presented by its deeply cut valleys and variously outlined mountains.

* The Geological Observer, 2d edition, pp. 562 and 574.

Plate II. embraces a country of a less picturesque character, although from the weather-beaten jagged summit of Croghan Kinshela, 1,987 feet above the sea, to the wooded banks and smooth meadows of the Ovoca, the scenery offers a great diversity. The index map of the country, which has been published by the Survey as a geological map, being on a scale of but one inch to the mile, can necessarily give only a general view of the geological features; the six-inch map, or townlands survey, on which the field observations were made, has been deemed too large for publication; but the details of that important part of it occupied by the mines, have been, as already noticed, published in a separate sheet on a far larger scale.*

Plate II. will however partly supply the want of a larger map in offering a view of the geological relations of the lodes and the structure of the neighbouring country. Its chief point of difference from the published index map is, that a distinct colour is given to a group of felspathic rocks, which throughout this and the neighbouring counties on the south play a prominent part. These masses, of which the Bell Rock at Lower Ballygahan, beetling above the main road, may be taken as a type, are composed of what has sometimes been termed petrosilex, or compact felspar, but may conveniently be termed felstone,† if by that name we understand a compound of felspar with free silica, mostly compact, but sometimes exhibiting minute crystals of felspar imbedded in a homogeneous paste. This kind of rock, which may readily be distinguished from quartz rock, by its weathering on the surface, and by its fusibility in thin splinters before the blow-pipe, occurs in a great variety of pale tints: it sometimes forms huge irregular bosses, in which no planes of separation, except joints like those of igneous rocks, are observable; at other times it is distinctly stratified, and often by the increased admixture of other detrital matter with its felspathic constituents, passes by so gradual a transition to the state of the argillaceous slates of the neighbourhood, that the line of demar-

* Plan and sections of the Ovoca mines, on a scale of 18 inches to a mile, published by the Geological Survey of Ireland.

† See Sedgwick's Letters to Wordsworth on the Geology of the Lake District of Cumberland and Westmoreland; and for the production of a similar rock by metamorphic action, Breithaupt, Die Paragenesis der Mineralien, p. 51. Freiberg. 1849.

cation drawn between the two is of a very arbitrary kind. Wherever represented in this map it appears to be what geologists term contemporaneous with the slates, i.e., to have been accumulated in thick or thin beds, and more or less intermingled with ordinary detritus, alternately with the slatey strata, possibly too, metamorphosed since its original deposition; but closely related as it is to dykes or intrusive veins, seen in some parts of the sea coast, it is a species of rock which may owe its presence to distinct modes of action, and may thus involve consequences requiring special study in given localities.

The geology of these regions at large will be described by the Director of the Geological Survey of Ireland, Mr. J. Beete Jukes; and the objects of this paper will have been attained, if it add a few facts to the stores of our knowledge of metalliferous districts, and illustrate the interest of localities not less deserving the attention of the capitalist than of every friend of the country, as developing the resources of the land, and fostering by the most legitimate means the prosperity of the people.

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MUSEUM OF PRACTICAL GEOLOGY
AND GEOLOGICAL SURVEY.

RECORDS

OF THE

SCHOOL OF MINES

AND OF

SCIENCE APPLIED TO THE ARTS.

VOL. I. PART IV.

MEMORANDUM.

In each Table of the imports of Copper and re-exports, pp. 419, 428, 439, 450, 464, *and* 478, *the word* "MANUFACTURES" *should be placed above the word* "VALUE" *in the last column.*

ERRATUM.

Page 419. *For £ s. d. under Total in the last line read* Tons. cwts. qrs.

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE.
PUBLISHED BY
LONGMAN, BROWN, GREEN, AND LONGMANS.

1853.

Statistics of the Produce of Copper, Tin, Lead, and Silver from the Mines of the United Kingdom, with the Imports and Exports of these Metals, from 1848 *to* 1852, *inclusive.*

By Robert Hunt,

KEEPER OF MINING RECORDS.

In the *Memoirs of the Geological Survey of Great Britain*, Vol. 1, will be found a *Notice of the Copper and Tin raised in Cornwall*, and in Vol. 2, Part 2, a Series of Tables giving the Produce of Lead Ore and Lead from 1845 to 1847 both inclusive, the Produce of Copper from the Mines of Devon and Cornwall for the same Years, and of the Sales of Copper Ore at Swansea from the Year 1804 to 1847. The following Returns therefore are a continuation of these to the present time.

Since the value of any Statistical Returns must depend entirely on their correctness, it is thought necessary to state the sources through which the information has been obtained from which the following tables have been compiled.

Copper. The ticketing papers, which are regularly published, of the sales in Cornwall and at Swansea have been used, but as a considerable quantity of copper ore is not

sold at public sales, the returns of the sales by private contract have been obtained from the Agents of the respective mines themselves and from the copper smelters, especially for this office; these have been added to the quantities sold by public sale.

Tin. With the exception of last year, when some of the mines published their sales of black tin or tin ore, the returns have been obtained principally from the tin smelters, who have afforded satisfactory replies to every inquiry. Several of the Agents of the tin mines have also furnished information of their produce, and it is hoped that a regular system of return from all the districts producing tin will shortly be arranged. Mr. Michael Williams and Mr. Thomas S. Bolitho have rendered much assistance in this division of the returns.

Lead. The ticketing papers of the lead sales in Flintshire, although not published, are regularly obtained (by favour) for this office. In addition to the information thus secured, every lead producing district throughout the United Kingdom has been communicated with, and each individual mine of any consequence consulted as to its produce of lead ore and lead. The readiness with which the returns are furnished from the lead mines and from the lead smelters in all parts of the country now renders it no very difficult task to arrive at correct results.

Silver. The system of obtaining the produce of silver has not yet been sufficiently organized to secure any very exact returns; a near approximation therefore is all that has been at present attempted. The practical acquaintance

possessed by Mr. John Taylor, has been of great value, and with the assistance rendered by Messrs. Walker and Co. has enabled me to approach to a tolerable degree of correctness.

The export and import tables have been compiled from the returns to the House of Commons.

1848.

COPPER.

COPPER ORES sold by PUBLIC TICKETINGS in CORNWALL and by PRIVATE CONTRACT during the year 1848.

Mines.	Ore.	Copper.				Amount.			Prod.
	Tons.	Tons.	cwts.	qrs.	lbs.	£	s.	d.	
Devon Great Consols -	16,374	1,684	3	0	0	93,418	6	0	10¼
Carn Brea - - - -	10,432	1,051	3	1	18	62,641	7	0	10 1/16
Par Consols - -	8,470	914	8	1	1	53,253	19	0	10⅛
Consolidated Mines - -	9,140	754	13	3	13	45,898	2	0	8½
United Mines - -	11,373	724	11	3	19	41,796	16	6	6⅜
Fowey Consols - -	6,015	568	2	2	19	32,146	6	0	9⅜ 1/16
Huel Seton - -	5,483	433	14	2	5	26,496	16	6	7⅞
North Roskear - -	5,489	433	12	2	6	26,072	8	0	7⅞
West Caradon - -	3,668	424	5	0	26	24,726	13	6	11½ 1/16
South Caradon - -	3,473	373	7	3	20	21,836	13	0	10¾
North Pool - - -	5,576	370	7	1	11	21,262	9	0	6⅝
Huel Friendship (East) -	2,787	346	12	1	17	20,665	19	6	12⅜ 1/16
South Huel Francis -	2,462	305	1	1	4	19,055	16	0	12⅜
Tincroft - - -	4,252	257	10	2	24	13,968	0	0	6 1/16
East Huel Crofty - -	3,100	227	19	1	24	13,453	6	6	7⅜
Tresavean - - -	3,723	227	11	3	20	12,910	17	6	6⅛
Camborne Vean &c. -	3,075	211	13	0	20	12,414	10	6	6⅞
South Huel Basset - -	2,111	201	1	3	6	11,999	4	6	9½
Levant - - -	1,776	177	12	1	6	9,857	3	0	10
Treviskey - - -	1,909	156	18	0	13	9,386	4	6	8⅛ 1/16
Bedford United Mines -	1,314	129	11	1	17	7,471	7	6	9⅞
Treleigh Consols - -	1,266	112	15	0	15	6,956	4	6	8⅞
Perran Saint George -	1,803	112	8	0	5	6,028	10	6	6¼
Tywarnhaile - -	1,788	110	11	1	25	6,089	14	6	6⅛ 1/16
Huel Comfort - -	2,264	104	5	1	26	5,393	4	6	4⅝
Condurrow - - -	1,550	102	5	1	2	5,736	17	0	6⅛ 1/16
Dolcoath - - -	1,254	95	2	1	10	5,587	16	0	7⅛ 1/16
South Roskear - -	1,095	87	19	2	12	5,312	17	0	8
Creegbraws - - -	1,299	86	13	1	1	5,002	17	0	6⅝ 1/16
Poldice - - -	1,127	81	9	1	26	4,859	11	0	7¼
West Treasury - -	944	78	11	2	6	4,648	2	6	8¼ 1/16
Huel Prosper - -	1,372	72	15	0	14	4,185	16	0	5¼ 1/16
Huel Bucketts - -	1,069	68	7	2	1	4,004	3	0	6⅜
Huel Agar - - -	997	66	4	1	27	3,749	11	0	6⅝
Huel Mary Consols - -	721	66	1	2	27	3,702	6	0	9⅛
Carried forward -	130,551	11,219	13	3	10	681,919	16	6	

Copper Ore sold by Public Ticketings, &c. in Cornwall—*continued.*

Mines.	Ore.	Copper.				Amount.			Prod.
	Tons.	Tons.	cwts.	qrs.	lbs.	£	s.	d.	
Brought forward -	130,551	11,219	13	3	10	651,989	16	6	
East Pool - - -	1,088	64	16	3	5	3,550	6	0	5 7/8 1/16
Mark Valley - -	1,209	61	0	2	17	3,295	18	6	5
Huel Ellen - - -	641	60	18	0	8	3,648	14	0	9 1/2
Grambler and St. Aubyn -	872	59	12	2	11	3,438	4	0	6 3/4 1/16
Huel Tremayne - -	864	58	6	2	8	3,130	6	6	6 3/4
Huel Alfred Consols -	1,148	57	3	3	22	3,125	5	0	5
Trethellan - - -	1,015	51	12	2	18	2,749	13	6	5 1/16
Wellington Mines - -	289	39	13	3	18	2,351	8	0	13 1/4
West Huel Jewell - -	689	38	15	0	21	2,127	19	0	5 5/8
Huel Jewell - -	495	37	2	2	22	2,278	15	0	7 1/8
Huel Andrew and Nargiles -	459	34	12	0	26	2,006	14	6	7 1/8
South Huel Fortune -	339	34	8	0	19	2,046	11	6	10 1/8
Holmbush - - -	398	33	11	3	20	1,926	0	0	8 3/8
Huel Sisters - -	365	29	4	2	27	1,729	1	0	8
North Basset - - -	344	28	16	3	21	1,799	19	6	8 3/8
Huel Phœnix - -	194	27	14	1	20	1,643	8	6	14 1/4
Charles-Town United -	208	26	6	2	5	1,528	8	0	12 5/8
South Tolgus - -	367	26	6	1	19	1,516	1	0	7 1/8
Huel Henry - -	311	24	16	2	1	1,469	16	0	8
Great Work - - -	143	23	8	2	1	1,438	0	0	16 3/8
Huel Mary - - -	270	21	7	1	7	1,225	12	6	7 1/8
West Huel Seaton - -	236	18	19	1	12	1,095	10	0	8
Tresavean Barrier - -	277	18	17	2	18	1,068	8	0	6 3/4 1/16
Huel Clifford - -	305	17	12	1	5	949	18	6	5 1/4
Huel Rodney - -	302	15	0	2	21	812	19	0	5
Huel Pink - - -	183	14	11	1	10	811	5	6	7 1/8 1/16
Huel Jane - -	286	14	9	0	19	738	18	6	5 1/16
Huel Williams - -	170	13	18	3	10	753	13	0	8 1/8 1/16
Gwinear Consols - -	262	13	13	1	4	709	2	6	5 1/8 1/16
Huel Harriet - -	281	13	12	1	27	724	13	6	4 3/4 1/16
Huel Maiden - -	194	12	3	3	4	702	11	6	6 1/4
Redruth Consols - -	215	10	8	3	15	567	0	0	4 7/8 1/16
West Fowey Consols -	109	9	15	0	0	534	19	6	8 7/8 1/16
Huel Gurlyn - -	118	9	8	3	23	598	19	6	8
Huel Tryphena - -	45	9	8	3	16	651	1	6	21
Gonamena - - -	75	9	7	2	16	566	12	6	12 1/4
Carried forward -	145,314	12,260	18	3	22	711,301	11	6	

Copper Ore sold by Public Ticketings, &c. in Cornwall—*continued.*

Mines.	Ore.	Copper.	Amount.	Prod.
	Tons.	Tons. cwts. qrs. lbs.	£ s. d.	
Brought forward -	145,314	12,260 18 3 22	711,301 11 6	
Huel Busy - - -	193	9 1 3 17	466 10 6	4⅝
East Seton - -	113	8 12 3 11	500 15 6	7⅞
Huel Vyvian - - -	92	8 6 3 11	461 17 0	9 1/16
Great Michell Consols -	157	8 3 3 9	404 8 6	5¼
Huel Gorland - -	105	8 3 1 25	509 1 0	7⅝
Lanivet Consols - -	133	8 1 2 3	409 16 6	5⅞
Botallack - - -	75	7 0 1 14	370 15 0	9¼ 1/16
Huel Prudence - -	114	5 18 3 0	297 1 0	5¼
Huel Brewer - -	124	5 3 2 12	240 16 6	4⅛ 1/16
Sundries - - -	1,276	92 7 1 21	5,128 4 0	7¼
Total -	147,701	12,421 19 2 5	720,090 17 0	Mean 8⅛

Copper Ore sold by Public Ticketing at Swansea in the year 1848, the sales by private contract, as far as they can be ascertained, being added.

Mines.	Ore.	Copper.	Amount.	Prod.
	Tons.	Tons. cwts. qrs. lbs.	£ s. d.	
Cobre - - -	17,564	3,019 1 2 5	192,389 0 0	17⅛ 1/16
Chili - - -	3,398	1,407 12 0 21	93,122 16 0	41⅜
Burra Burra - - -	4,047	1,233 7 3 8	84,117 2 6	30½
Cuba - - -	7,486	1,097 7 1 25	69,443 19 0	14⅝
Bearhaven - - -	5,872	583 8 1 10	36,818 4 6	9⅞ 1/16
Knockmahon - -	4,674	383 16 1 25	24,470 0 6	8¼
Copiapo - - -	765	206 6 2 3	14,136 16 6	27
Kapunda - - -	661	156 9 1 25	10,751 11 6	23⅝
Santiago - - -	716	119 3 2 4	7,538 16 6	16⅜
Holyford - - -	302	73 18 1 9	5,465 2 6	24⅛
Ballymurtagh - -	1,449	71 19 1 2	4,184 9 0	5
Recompensa - - -	460	55 19 1 26	3,050 14 0	12⅛
Kanmantoo - -	321	55 13 1 2	3,162 5 6	17½ 1/16
Princess Royal - -	196	55 3 2 12	4,066 10 6	28⅛
Montacute - - -	93	19 13 2 4	1,247 2 0	21⅛ 1/16
Paringa - - -	82	18 0 3 5	1,016 16 0	22
Lacksmore - - -	152	17 13 1 8	1,164 12 6	11⅜
New Zealand - -	121	13 19 1 16	900 8 0	11⅛
Cronebane - - -	137	8 12 0 5	532 9 0	6½
Adelaide - - -	33	8 3 1 11	549 9 0	24⅜ 1/16
Australia - - -	40	7 16 0 0	501 0 0	19⅜
Aberdovey - - -	66	7 13 3 27	520 6 0	11⅜
Cantabra - - -	43	6 12 1 27	511 15 6	15½ 1/16
Caridad - - -	20	5 7 0 0	417 10 0	26¼
Sundries - - -	665	39 18 3 25	2,339 14 6	6
Total -	49,363	8,672 18 0 15	562,418 11 0	Mean 17⅛ 1/16

COPPER imported into the United Kingdom in 1848.

Ore.	Regulus.	Cast Copper.	Old Copper.	Bars, Rods, &c.	Plates, Coins.	Value.
Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	£ s. d.
50,053 2	124 2	512 15	153 16	1,074 2	9 0	9,200 9 5

Of this Imported Copper the following places furnished the largest Quantities.

	Ore.	Regulus.	Cast Copper.	Bars and Rod.
	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.
South Australia	7,783 14	—	—	—
New South Wales	3,688 19	—	—	—
Van Dieman's Land	543 13	—	—	—
New Zealand	70 0	—	—	—
Cuba	30,679 0	—	—	—
Chili	4,503 0	124 5	121 18	967 19
Peru	1,882 0	—	—	—
Western Coast of Africa	101 0	—	—	—
France	45 6	—	94 0	—
Spain	120 0	—	—	—
Italy	126 0	—	—	—
China	388 0	—	—	—

Of this Quantity there was re-exported—

Ore.	Bricks, Pigs, &c.	Old Copper.	Bars, Rods, &c.	Value.
Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	£ s. d.
320 11 3 4	186 5 2 21	38 19 2 16	125 0 0 26	6,011 0 0

BRITISH COPPER exported.

Bricks and Pigs.	Coin.	Sheet, Nails, Yellow Metal.	Wire.	Wrought Copper of other Sorts.	Total.
Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	£ s. d.
4,261 5	21 12	8,947 7	16 11	219 12	13,466 8 0

TIN.

PRODUCE of TIN ORE in CORNWALL and DEVON in 1848.
10,176 Tons.

In the Ten Years preceding the 1st January 1849 the TIN and TIN ORE exported to Foreign Parts was as follows:—

	Penzance.	St. Ives.	Truro.	Fowey.	TOTAL.
	Cwts. qrs.	Cwts. qrs.	Cwts. qrs.	Cwts.	Cwts. qrs.
1839	1,657 2	1,804 4	4,246 3	70	7,779 1
1840	5,904 1	1,753 0	6,156 3	- - -	13,814 1
1841	3,719 1	240 0	1,480 0	- - -	5,439 2
1842	7,236 1	6,277 0	6,390 0	- - -	19,904 2
1843	2,592 0	2,829 0	2,731 0	- - -	8,152 4
1844	1,202 2	1,000 0	5,324 0	- - -	7,527 1
1845	442 0	1,461 0	- - -	- - -	1,903 2
1846	2,803 0	3,267 0	- - -	- - -	6,070 1
1847	1,543 0	3,250 0	800 0	- -	5,594 0
1848	1,571 0	200 0	- - -	- - -	1,771 0

TOTAL of TIN exported in 1848.

	Tons.	cwts.	qrs.	lbs.
Foreign Tin - -	417	0	2	4
British Tin - -	1,771	5	3	10

TIN imported in 1848.

	Tin.		Tin Ore.	
	Tons.	cwts.	Tons.	cwts.
From Holland - -	73	19	—	
„ Belgium - -	26	11	—	
„ France - - -	-	- -	33	13
„ Spain - -	21	3	—	
„ Cape of Good Hope -	0	18	—	
„ East Indies - -	7	7	—	
„ Singapore - -	136	3	—	
„ China - - -	14	11	—	
„ Peru - - -	18	0	—	
Total Import -	298	15	33	13

LEAD.

PRODUCE of LEAD ORE and LEAD in the UNITED KINGDOM for the Year 1848.

Total of Lead.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead.
Tons.		ENGLAND.	Tons.	Tons.	
6,614	Cornwall - -	Callington - -	957	632	
		Huel Mary Ann - -	334	250	
		Huel Trelawney -	413	298	
		Huel Trehane - -	422	279	
		Herodscoombe - -	—	—	
		Herodsfoot - -	721	570	
		East Huel Rose -	5,333	3,191	
		North Huel Rose -	80	49	
		Cargol - - -	964	577	6,614
		Oxnams - -	470	288	
		Huel Rose - -	399	239	
		Cubert - - -	68	41	
		Holmbush - -	154	90	
		Leman - - -	—	—	
		Great Callestock Moors -	—	—	
		Huel Concord - -	—	—	
		Callestock - -	179	110	
844	Devonshire -	Tamar - - -	1,022	631	
		Huel Adams - -	56	30	
		East Tamar Consols -	237	173	844
		Huel Friendship -	9	5	
		Huel Betsey - -	6	3	
		Lydford Consols -	4	2	
5,684	Cumberland -	Rampgill - -	424	282	
		Scaleburn - - -	238	156	
		Carrs and Hanging Shaw	146	97	
		Capel Cleugh - -	139	92	
		Small Cleugh - -	31	21	
		Middle Cleugh - -	30	20	
		Guddamgill - -	50	33	
		Long Cleugh - -	1,664	1,142	
		Browngill - -	603	400	
		Bentyfields Veins -	35	21	
		Cowperdyke Heads -	14	9	
		Brigalburn Veins -	244	162	
		Brownley Hill Veins -	227	143	
	Alston Moor Mines.	Bentyfield Sun. V. E. End.	119	80	4,264
		Blagill Veins - -	76	51	
		Carrs West of Nent Vein -	39	26	
		Grass Fields Veins -	31	20	
		Galligill Syke Veins -	176	117	
		Galligill Burn - -	24	16	
		Hudgill Burn - -	188	120	
		Holyfields Veins - -	58	38	
		Wellgill Cross Vein -	98	66	
		Rodderup Cleugh West End	1,470	980	
		Tyne Bottom Veins -	80	54	
		Park Grove Sun Vein -	21	14	
		Low Birchy Pank -	19	12	
		Dowkeburn West End -	95	63	
		Sundry Mines under 10 tons	44	29	
13,142	Carried forward.		18,211	11,722	

Produce of Lead Ore and Lead in the United Kingdom for the Year 1848—*continued.*

Total of Lead.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead.
Tons. 13,142	Brought forward.		Tons. 18,211	Tons. 11,722	
	Cumberland—*cont.*	Roughtingill - -	—	—	
		Driggith Beck Waste	30	15	
		Dry Gill Mine -	40	27	
		Cumberland - -	—	—	
		Greensides - -	1,560	1,200	
		Woodend - -	36	24	
		Force Cragg - -	43	32	1,120
		Keswick Mine - -	20	14	
	Tynehead Mines.	Slaty Syke - -	47	35	
		Calvert - - -	11	6	
		Dozey - - -	13	9	
		Slow Craigh - - -	25	16	
		Crossfell Mines - -	44	30	
		Sundry Mines under 10 tons	20	12	
14,658	Durham and Northumberland	East and West Allendale and Weardale - -	13,230	9,080	
		Teesdale Mines - -	3,327	2,490	
		Yarnberry - -	100	75	
		Silver Tongue - -	139	95	
		Derwent Mines - -	1,480	1,046	
		Stanhope Burn - -	220	160	14,658
		Hollywell - -	67	48	
		Lane Head - -	24	17	
		Aller Gill - -	12	8	
		Bollihope - - -	13	9	
		Fallow-field - -	61	45	
		Whitfield - -	142	105	
388	Westmoreland -	Dufton and Silverband -	246	184	388
		Hilton and Marton -	273	204	
3,370	Derbyshire -	Sundry Mines - -	5,185	3,370	3,370
2,762	Shropshire -	Snailbeach - -	3,463	2,436	
		White Grit and Batholes -	506	239	
		Bog Mine - -	139	72	2,762
		Pennerley - - -	22	15	
		Round Hills - -	—	—	
29	Somersetshire -	Mendip Hills - -	41	29	29
4,793	Yorkshire -	Swale Dale and Arkendale	4,053	3,040	
		Cononley - -	699	437	
		Grassington, including Yarnbury and Coal-grove Beck - -	1,159	707	4,793
		Pateley District - -	937	609	
39,142	Carried forward.	Total - -	54,538	39,142	

Produce of Lead Ore and Lead in the United Kingdom for the Year 1848—*continued.*

Total of Lead.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead.
Tons.			Tons.	Tons.	
39,142	Brought forward.	WALES.			
3,180	Cardiganshire -	Lisburne Mines - -	2,454	1,624	
		Cwm-ystwyth - -	120	71	
		Esgair-hir - - -	116	70	
		Cwm-sebon - -	31	17	
		Llanfair - -	80	53	
		Goginan - - -	1,238	816	
		Gogerddan Mines -	243	162	
		Nanty-y-creiau - -	17	10	
		Pen-y-bont-pren -	38	22	
		Cefn-cwm-brwyno -	36	24	3,180
		Llwyn-malys - -	51	33	
		Bwlch-cwm-erfin -	40	26	
		Bwlch-Consols - -	289	192	
		Nanteos - -	50	30	
		Aberystwith (small mines)	20	10	
		Llanymaron - -	11	5	
		Llanbadarn - -	33	18	
		Bron-berllan - -	15	7	
14	Carnarvonshire -	Llanrwst - - -	—	—	
		Penrhyn-du - -	21	14	14
204	Carmarthenshire	Nant y Mwyn - -	307	204	204
	Denbighshire -	Llangollen - -	—	—	
7,069	Flintshire -	Talargoch { Maes-yr erwddu / Coetia Clys }	1,500	980	
		Fronfownog - -	1,695	1,168	
		Hendre - - -	1,040	838	
		Longley - -	—	—	
		Maes-y-safn - -	1,138	824	
		Pen-yr-benblas - -	1,160	819	
		Mold Mines - -	219	153	
		Long Rake - -	39	21	
		Milwr - - -	117	81	
		Penybryn - -	—	—	
		Dingle and Deep Level -	887	643	
		Parry's Mine - -	21	15	
		Trelogan - -	15	10	
		Westminster Mines -	659	451	
		Halkin Hall - -	39	26	
		Garreg-y-boeth - -	6	4	7,069
		Afongoch - -	—	—	
		Bodelwyddan - -	106	69	
		Belgrave - -	375	261	
		Bryng-gwyrog - -	11	7	
		Holywell - -	—	—	
		Jamaica - - -	835	599	
		Bwlch-y-ddlaufryn -	20	16	
		Marion - - -	—	—	
		Gwern-y-mynydd -	18	13	
		Mostyn - - -	13	8	
		Bagillt (ore sold at) -	46	20	
		Billings - -	45	20	
		Caelanycraig - -	14	7	
		Mostyn - - -	12	5	
		Clwtmilitia - -	26	11	
49,609	Carried forward		15,286	10,467	

Produce of Lead Ore and Lead in the United Kingdom for the Year 1848—*continued.*

Total of Lead.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead.
Tons. 49,609	Brought forward.		Tons. 15,286	Tons. 10,467	
601	Montgomeryshire	Llangynnog - -	51	31	601
		Cae-conroy - -	33	20	
		Rhos-wydol - -	26	15	
		Dwn-gwm or Dyfngwm -	13	9	
		Craig-Rhiwarth -	27	16	
		Bryndail and Pen-y-clyn -	155	100	
		Gorn - - -	43	30	
		Machynlleth, including Delife	545	360	
		Nantmelyn - -	19	13	
		Frontballan - -	15	7	
54	Merionethshire -	Barmouth (port of) -	—	—	54
		Cowarch - -	74	42	
		Tyddynglwadus - -	18	12	
			16,305	11,122	
		IRELAND.			
	Clare - -	Kilbricken - -	—	—	545
		Ballyhicky - - -	—	—	
545	Down - -	Newtownards - -	616	366	
		Conlig - - -	314	179	
202	Tipperary -	Shallee - -	340	202	202
	Monaghan -	Bond and Newry -	—	—	
325	Wicklow -	Glenmalure - -	45	30	325
		Luganure - -	422	295	
116	Waterford -	Barristown - -	175	116	116
		Total -	1,912	1,188	
		SCOTLAND.			
376	Ayrshire -	Woodhead - -	450	320	376
		Afton Lead Mines -	80	56	
141	Argyleshire -	Strontion Mines - -	236	141	141
	Dumbartonshire	Dumbarton - -	—	—	369
369	Kircudbrightshire	Caernsmore - -	476	311	
		Cairsphairn - -	—	—	
		Black Craig -	86	58	
200	Lanarkshire -	Lead Hills Mine -	300	200	200
650	Dumfrieshire -	Wanlock head - -	960	650	650
		Total -	2,588	1,736	
		ISLE OF MAN.			
1,665	Isle of Man -	Foxdale Mines, including Peel's Shipment, &c. -	1,566	1,034	
		Laxey - - -	695	461	
		Douglas - -	260	170	
		Mona - - -	—	—	
54,853		Total -	2,521	1,665	

TABLE showing the TOTAL QUANTITY of LEAD ORE raised and LEAD smelted in the United Kingdom in 1848.

	Lead Ore.	Lead.
	Tons.	Tons.
England - - -	54,538	39,142
Wales - - -	16,305	11,122
Ireland - - -	1,912	1,188
Scotland - - -	2,588	1,736
Isle of Man - -	2,521	1,665
Total -	77,864	54,853

LEAD ORE and LEAD Imported and Exported in 1848.

IMPORTED.

Lead Ore.		Lead.
Tons.		Tons.
1,298	Pig and Sheet - - -	3,788
	Retained for home consumption -	2,157

EXPORTED.

135	Pig and Rolled Lead - -	4,977
	Shot - - - -	1,151
	Litharge, Red and White Lead -	2,292
	Foreign Lead, in sheet and pig -	3,747

The Welsh Sales include also the following ores:—

	Tons.
Australian - - -	69
Belgian - - - -	85
German - - - -	44
Portugal - - -	79
Prussian - - - -	112
Sardinian - - - -	112

1849.

COPPER.

COPPER ORES sold by PUBLIC TICKETINGS and by PRIVATE CONTRACT in CORNWALL during the year 1849.

Mines.	Ore.	Copper.				Amount.			Prod.
	Tons.	Tons.	cwts.	qrs.	lbs.	£	s.	d.	
Devon Great Consols	15,777	1,508	12	1	0	96,934	13	0	9 1/8 1/16
Carnbrea	10,086	986	1	1	17	66,632	6	6	9 3/4
United Mines	12,228	736	9	2	2	47,249	1	0	6
Par Consols	7,372	663	13	3	2	43,102	10	0	9
Consolidated Mines	7,906	626	5	2	23	41,863	19	6	7 7/8 1/16
Fowey Consols	6,302	564	0	0	5	36,449	5	6	8 7/8 1/16
West Caradon	3,966	439	13	2	11	29,872	19	6	11 1/16
North Pool	6,447	433	0	1	8	27,717	1	0	6 3/8 1/16
North Roskear	5,660	420	4	1	16	26,756	4	0	7 3/8 1/16
Huel Seton	4,953	333	7	2	11	21,577	5	0	6 3/4
South Basset	3,188	322	5	2	9	22,117	8	6	10 1/8
South Caradon	2,965	304	16	0	3	20,508	7	0	10 1/2
Tywarnhaile	4,721	293	3	0	23	18,718	0	6	6 1/8 1/16
Tincroft	4,765	281	13	3	4	17,051	14	6	5 7/8 1/16
Huel Friendship	2,484	275	18	0	19	18,988	11	6	11 1/8
South Huel Francis	1,844	246	18	0	25	17,448	16	6	13 3/8
Trevisky	2,421	232	6	0	9	15,849	10	0	9 1/8 1/16
East Huel Crofty	3,217	230	13	3	15	14,541	13	6	7 1/8 1/16
Tresavean	3,334	184	7	2	24	11,484	3	0	5 1/8
Camborne Vean	2,775	180	6	1	23	11,495	15	0	6 1/8
Levant	1,904	170	18	2	17	10,972	13	6	9
Bedford United Mines	1,415	148	12	3	2	10,150	16	6	10 1/8
Huel Comfort	3,084	128	9	2	21	7,405	0	0	4 1/8 1/16
West Buller	1,165	125	8	0	20	8,968	2	0	10 3/4
Condurrow	1,493	115	19	3	14	7,647	15	0	7 1/2
Treleigh Consols	1,254	102	11	0	16	6,872	19	0	8 1/8 1/16
West Treasury	1,362	101	17	0	24	6,897	7	0	7 1/8
Huel Agar	1,493	91	9	0	23	5,894	17	0	6 1/4
Huel Mary	1,197	86	8	0	26	5,670	15	6	7 1/2
Huel Tremayne	1,646	85	4	1	1	5,030	18	0	5 1/8 1/16
South Tolgus	962	83	6	2	10	5,671	8	0	5 5/8 1/16
Perran Saint George	828	78	4	3	16	5,196	16	0	9 3/8 1/16
Dolcoath	1,028	77	10	0	21	5,197	7	6	7 1/8 1/16
East Pool	1,136	66	17	1	26	4,138	8	0	5 7/8
Mark Valley	1,359	66	7	0	16	4,182	16	6	4 7/8
Wellington Mines	672	62	5	2	10	4,253	12	0	9 1/8
West Huel Seaton	739	58	19	1	7	3,981	4	6	8
South Roskear	877	56	3	3	11	3,588	1	0	6 3/8 1/16
Poldice	791	55	0	0	16	3,699	16	0	6 7/8 1/16
Trethellan	1,287	54	17	1	16	3,132	8	0	4 1/8
Creegbraws	747	53	6	2	16	3,371	7	6	7 1/4
Huel Mary Consols	656	49	19	3	7	3,081	19	0	7 3/8
West Fowey Consols	459	41	9	1	26	2,810	9	0	9
Holmbush	454	36	3	3	4	2,356	3	0	8
Huel Ellen	403	35	4	0	8	2,284	14	0	8 1/4
Huel Henry	338	28	9	2	21	1,855	9	6	8 1/4 1/16
Grambler and St. Aubyn	398	28	7	0	9	1,827	15	6	7 1/8
Charlestown United	255	26	19	2	27	1,840	2	0	10 1/2 1/16
West Huel Jewell	400	25	0	0	13	1,617	3	6	6 1/4
Sout Huel Fortune	238	24	2	2	27	1,610	4	0	10 1/8
Huel Pink	354	24	1	2	6	1,562	10	0	6 3/4 1/16
Huel Vyvian	237	15	2	0	25	887	14	0	6 1/8
Carried forward	143,042	11,468	16	1	23	750,017	17	0	

Copper Ore sold by Public Tickets, &c. in Cornwall—*continued.*

Mines.	Ore.	Copper.				Amount.			Prod.
	Tons.	Tons.	cwt.	qrs.	lbs.	£	s.	d.	
Brought forward -	143,042	11,468	16	1	23	750,017	17	0	
Huel Phœnix - -	150	13	16	0	0	962	0	6	9½ 1/16
West Trethellan - -	239	12	17	0	16	826	2	6	5⅝
South Crinnis - -	156	12	13	0	5	817	17	6	8½
Huel Alfred Consols -	256	12	1	2	26	687	9	0	4¾
Huel Maiden - -	171	11	3	1	22	742	4	6	6½
Huel Bucketts - -	189	10	7	3	19	630	14	6	5½
Huel Busy - - -	208	9	15	1	10	579	12	6	4⅝ 1/16
Great Work - -	95	9	12	3	16	650	0	0	10½ 1/16
Huel Penhale - -	96	8	4	2	22	569	17	0	8½ 1/16
Huel Prudence - -	164	8	2	1	11	423	15	6	4⅞ 1/16
Huel Jewell - - -	100	6	16	0	20	436	14	0	6¾ 1/16
Polberro - - -	35	5	17	1	0	416	10	0	16⅝ 1/16
Huel Prosper - -	115	5	6	1	2	294	9	0	4⅝
Sundries - - -	1,310	88	2	1	26	5,559	15	6	6⅝ 1/16
Total -	146,326	11,683	13	0	22	763,614	19	0	Mean 8

Copper Ore sold by Public Ticketings in Swansea in the year 1849, and by Private Sales.

Mines.	Ore.	Copper.				Amount.			Prod.
	Tons.	Tons.	cwts.	qrs.	lbs.	£	s.	d.	
Cobre - - -	19,409	3,336	3	2	21	247,618	16	6	17½ 1/16
Burra Burra - -	7,238	2,123	2	2	12	159,597	11	0	29½ 1/16
Bearhaven - - -	5,812	607	2	3	30	45,868	16	0	10⅝ 1/16
Cuba - - -	2,697	421	17	0	5	31,380	8	0	15⅝
Knockmahon - -	2,787	247	1	0	25	18,046	3	0	8⅞
Santiago - - -	1,518	236	9	2	0	18,601	16	0	15½ 1/16
Copiapo - - -	710	196	16	3	1	15,498	14	0	27½
Chili - - - -	213	64	6	0	12	5,267	16	6	30½ 1/16
Kapunda - - -	266	59	7	1	26	4,708	5	0	22¼ 1/16
Ballymurtagh - -	1,059	56	3	2	7	3,885	8	6	5½ 1/16
Kawaw - - -	307	43	17	2	27	3,111	11	0	14½ 1/16
Havana - - -	209	39	1	1	10	3,188	11	6	18⅝ 1/16
Giburra - - -	151	19	4	0	1	1,539	2	0	12¾
Cabral - - -	96	12	17	2	11	1,133	12	0	13⅜ 1/16
Lackamore - -	114	10	3	2	7	745	6	0	8⅞ 1/16
Aberdovey - - -	101	9	15	0	20	733	13	6	9⅜
Guildford Slag - -	113	8	16	2	21	596	13	6	7¾ 1/16
Forest Slag - -	156	5	17	2	27	356	6	0	3¾
Sundries - - -	637	41	18	0	21	2,707	6	0	6½ 1/16
Total -	43,593	7,540	2	3	22	564,585	16	0	Mean 17¼ 1/16

COPPER imported into the United Kingdom in 1849.

Ore.	Regulus.	Cast Copper.	Old Copper.	Bars, Rods.	Plates and Coin.	Value.
Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	£ s. d.
46,237 0	1,196 4	667 12	228 4	1,922 15	18 6	25,338 11 10

Of this Imported Copper the following countries furnished the largest quantities.

	Ore.	Regulus.	Cast Copper.	Bars and Rods.
	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.
South Australia	13,753 4	- - -	1 10	—
New South Wales	2,166 0	323 7	—	—
Van Dieman's Land	454 17	- - -	- - -	2 0
New Zealand	—	—	—	—
Cuba	24,765 9		—	—
Chili	3,449 17	580 19	461 15	1,189 4
Peru	1,160 0	- - -	98 18	21 3
West Coast of Africa	36 5	—	—	—
France	29 16	182 10	0 3	—
Spain	112 2	—	—	—
Italy	91 12	- - -	- - -	9 18
China	—	—	—	—

Of this quantity there was re-exported—

Ore.	Bricks and Pigs.	Old Copper.	Bars, Rods, &c.	Value.
Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	Tons. cwts. qrs.	£ s. d.
712 9 1 27	196 3 2 17	60 19 2 1	440 3 2	21,307 0 0

BRITISH COPPER exported.

Bricks and Pigs.	Coins.	Sheets, Nails, Yellow Metal.	Wire.	Wrought Copper of other Sorts.	Total.
Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.
7,349 16	9 19	12,826 17	25 14	267 14	20,480 3

TIN.

PRODUCE of TIN ORE in DEVON and CORNWALL in 1849:
10,719 Tons.

TIN imported in 1849.

	Tin.	Tin Ore.
	Tons. cwts.	Tons. cwts.
From Holland - -	104 6	0 10
„ France - -	- - -	6 10
„ Portugal - -	- - -	0 2
„ Spain - -	31 9	—
„ East Indies (exclusive of Singapore.)	294 15	—
„ Singapore - -	1,145 4	—
„ China - -	195 12	—
„ Chili - - -	2 1	—
„ Peru - -	17 15	—
Total -	1,791 2	7 2

TIN exported in 1849.

	Tin.
	Tons. cwts. qrs. lbs.
Foreign Tin - -	446 19 3 18
British Tin - -	1,764 12 0 5

LEAD.

PRODUCE of LEAD ORE and LEAD in the UNITED KINGDOM for the Year 1849.

Total of Lead. — Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. — Districts.
Tons.		ENGLAND.	Tons. cwts.	Tons. cwts.	
6,733·0	Cornwall -	Callington - - -	625 0	422 0	
		Huel Mary Ann - -	873 0	655 0	
		Huel Trelawney - -	1,296 11	934 0	
		Huel Trehane - - -	459 12	290 0	
		Tregorden - - -	28 16	20 0	
		Herodscoombe - -	—	—	
		Herodsfoot - - -	1,050 0	830 0	
		East Huel Rose - -	4,758 15	2,856 0	
		Huel Penhale - -	50 0	35 0	
		Huel Golden - - -	80 0	56 0	
		North Huel Rose - -	75 14	46 0	
		Cargol - - -	505 3	303 0	
		Oxnams - - -	269 5	164 0	
		Huel Rose - - -	107 0	70 0	
		Cubert - - -	—	—	
		Holmbush - - -	102 0	61 0	
		Leman - - -	—	—	
		Great Callestock Moors -	—	—	
		Huel Concord - -	—	—	
		Callestock - - -	—	—	
		Carthew Consols - -	45 0	31 0	
1,172·0	Devonshire -	Tamar - - -	1,106 0	636 0	
		Huel Adams - -	382 0	210 0	
		East Tamar Consols - -	336 0	200 0	
		Huel Friendship - -	5 0	3 0	
		Lydford Consols - -	—	—	
		South Tamar Consols -	176 0	123 0	
7,178·7	Cumberland -	Browngill - - -	582 18	407 0	
		Rampgill - - -	418 10	292 0	
		Scaleburn - - -	169 17	119 0	
		Carrs and Hanging Shaw -	174 7	122 0	
	Governor and Company Mines -	Capel Cleugh - -	400 16	280 0	
		Small Cleugh - - -	35 1	24 0	2,939
		Middle Cleugh - -	47 7	33 0	
		Guddamgill - - -	46 0	32 0	
		Long Cleugh - - -	2,224 10	1,554 0	
		Bentyfield Sun Vein - -	26 18	18 0	
		Cowperdyke Heads - -	80 18	56 0	
		Cowhill - - -	4 10	2 0	
		Bentyfield Sun. S. E. End -	105 0	73 0	
		Brigal Burn - - -	209 6	146 0	
		Brownley Hill - -	252 0	176 1	
		Blagill Vein - - -	63 6	46 0	
		Carrs West of Nent Vein -	30 4	21 0	
		Black Syke - -	18 12	12 0	
		Hudgill Burn - -	14 0	10 0	
		Fore Shield - - -	24 5	17 0	
	Alston Mines	Farnbury Vein - -	28 19	20 1	
		Grassfield - - -	34 17	23 1	
		Galligill Syke - -	132 2	92 0	
		Drygill Mine - -	50 2	30 0	
15,123·7	Carried forward.		17,505 1	11,550 3	

Produce of Lead Ore and Lead in the United Kingdom for the Year 1849—*continued.*

Total of Lead. Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. Districts.
Tons.			Tons. cwts.	Tons. cwts.	
15,123·7	Brought forward.		17,705 1	11,550 3	
	Cumberland— *continued.*	Woodend	32 0	23 0	
		Force Cragg	27 6	18 0	
	Alston Mines— *continued*	Keswick Mine	56 16	35 0	
		Hudgill Burn	160 13	112 0	
		Calvert	58 11	41 0	
		Holyfield	16 4	11 0	599·6
		North Grain Cross Vein	0 16	0 4	
		Crossfell Mine	155 0	97 0	
		Thorngill West End	29 4	20 0	
		Wellgill Cross Vein	87 16	60 0	
		Greensides	1,820 0	1,300 0	
	Mines West of Tyne.	Rodderup Cleugh, West End	1,297 12	908 0	
		Tyne Bottom	54 12	37 0	1,005
		Dowke Burn, West End	86 16	60 0	
		Morley Fell	17 13	12 0	
	Langley Barony	Rodderupp Fell	1,152 0	801 0	851
		Sundries under 10 tons	62 0	38 0	
13,215·6	Durham and Northumberland	East and West Allendale and Weardale	13,362 0	9,162 0	9,162
		Teesdale Mines (including South Yarnbury)	3,404 8	2,576 0	2,576
		Silver Tongue	—	—	
		Derwent Mine	1,389 0	1,001 0	
		Stanhope Burn	—	—	
		Hollywell	80 0	51 0	
		Lane Head	13 17	8 5	
		Aller Gill	—	—	
		Bollihope	8 8	5 1	
		Fallow-field	194 16	88 0	
		Whitfield	80 17	54 0	
		Settling Stones	440 0	260 0	
		Pow Cross	7 0	4 0	
		Capton	9 12	6 0	
457·0	Westmoreland	Dufton and Silverband Hilton and Marton	601 12	457 0	
4,420·0	Derbyshire	Sundry Mines	6,800 0	4,420 0	
2,315·0	Shropshire	Snailbeach	3,196 0	2,301 0	2,301
		White Grit and Batholes	—	—	
		Bog Mine	20 0	14 0	
		Pennerley	—	—	
		Round Hills	—	—	
41	Somersetshire	Mendip Hills	50 0	41 0	41
5,596·18	Yorkshire	Swale Dale and Arkendale	4,954 0	3,648 0	3,648
		Cononley	588 4	395 7	
		Grassington, including Yarnbury and Coalgrove Beck	1,231 6	810 11	
		Pateley District	905 0	591 0	591
		Nithsdale	74 0	52 0	
		Kettlewell and Coniston Liberty	154 0	100 0	
41,168·11		Total	60,124 0	41,168 11	

Produce of Lead Ore and Lead in the United Kingdom for the Year 1849—*continued.*

Total of Lead. — Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. — Districts.
Tons.			Tons. cwts.	Tons. cwts.	
		WALES.			
3,895	Cardiganshire -	Lisburne Mines - -	2,733 0	1,804 0	1,804
		Cwm-ystwyth - - -	583 0	333 0	
		Esgair-hir - -	—	—	
		Cwm-sebon - - -	55 0	33 0	
		Llanfair Clydogau - -	206 0	134 1	
		Goginan - - -	1,160 0	766 0	766
		Gogerddan Mines - -	131 0	87 0	
		Nanty-y-creiau - -	—	—	
		Pen-y-bont-pren - -	12 0	7 0	
		Cefn-cwm-brwyno - -	10 0	7 0	
		Bwlch Consols - -	635 0	425 0	425
		Nanteos - - -	177 0	106 0	
		Aberystwyth (small mines) -	31 0	20 0	
		Llanymaron - - -	—	—	
		Llanbadarn - -	—	—	
		Bron-berllan - - -	—	—	
		Brynarian - - -	40 0	28 0	
		Cwm-erfin - - -	116 0	78 0	
		Daren - - -	29 0	20 0	
		Eisteddfodd - - -	20 15	14 0	
		Llwyn Malys - -	32 0	21 0	
		Bwlch-cwm-erfin - -	18 0	12 0	
19	Carnarvonshire -	Llanrwst - - -	18 0	10 0	
		Penrhyn du - -	—	—	
		Lliwedd (Snowdon) - -	12 0	9 0	
1,189	Carmarthenshire	Nant-y-Mwyn - -	1,775 10	1,189 0	1,189
	Denbighshire -	Llangollen - - -	—	—	
7,448	Flintshire -	Talargoch { Maes-yr-erwddu / Coetia Llys }	1,470 0	916 0	916
		Fronfownog - - -	1,213 0	825 0	
		Hendre - - -	1,013 0	811 0	
		Maes-y-safn - - -	995 0	726 0	
		Pen-yr-henblas - -	1,044 0	731 0	
		Mold Mines - - -	154 0	108 0	
		Long Rake - - -	68 10	38 0	
		Milwr - - -	642 0	469 0	
		Penybryn - - -	—	—	
		Dingle and Deep Level -	1,136 0	829 0	
		Parry's Mines - -	—	—	
		Westminster Mines - -	585 0	380 0	
		Halkin Hall - -	20 0	13 0	
		Bodelwyddan - - -	15 0	10 0	
		Belgrave - - -	350 0	245 0	
		Bryn-gwyrog - -	—	—	
		Holywell Level - -	14 0	10 0	
		Jamaica - - -	610 0	433 0	
12,551	Carried forward		17,123 15	11,647 0	

Produce of Lead Ore and Lead in the United Kingdom for the Year 1849—*continued.*

Total of Lead. — Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. — Districts.
Tons. 12,551	Brought forward		Tons. cwts. 17,123 15	Tons. cwts. 11,647 0	
	Flintshire—*cont.*	Bwlch-yd-daufryn	—	—	
		Billings	20 5	10 0	
		Clwtmilitia	23 0	11 0	
		Aberdune	65 10	46 0	
		Bryndigri	20 10	15 0	
		Gyrn	11 15	8 0	
		Pant-du	14 10	10 0	
		Pant-y-celyn	216 0	151 0	
		Pant-y-groes	20 0	14 0	
		Pant-y-ne	12 5	8 0	
		Pant-y-ffryth	40 0	28 0	
		Strong Croft	13 0	9 0	
		Sundries (under 10 tons)	115 10	81 0	
		Talacre	615 0	430 0	
		Pentire Glase	87 0	61 0	
		Level Newyd	32 0	22 0	
808	Montgomeryshire	Llangynnog	17 0	10 0	
		Cae-conroy	189 10	118 0	
		Rhos-wydol	98 0	57 0	
		Dwn-gwm or Dyfngwm	21 0	15 0	
		Craig-Rhiwarth	28 0	17 0	
		Bryndail	76 5	54 0	
		Gorn	48 0	34 0	
		Machynlleth, including Delife	588 0	388 0	
		Nantmelyn	30 0	21 0	
		Pen-y-clyn	117 0	82 0	
42	Merionethshire	Barmouth (Port of)	—	—	
		Cowarch	—	—	
		Tyddyngwladus	—	—	
		Dolgelly	18 0	11 0	
		Eagles Rock	40 0	24 0	
		Bwlch-y-Plwm	11 0	7 0	
13,401		Total	19,711 15	13,401 0	
		IRELAND.			
21·0	Clare	Kilbricken	—	—	
		Ballyhickey	—	—	
		Castleblayney	30 10	21 0	
924·0	Down	Newtownards	1,300 0	726 0	
		Conlig	347 0	198 0	
14·0	Cork	Bantry	24 0	14 0	
197·0	Tipperary	Shallee	329 0	197 0	
	Monaghan	Bond and Newry	—	—	
1156·0			2,030 19	1,156 0	

Produce of Lead Ore and Lead in the United Kingdom for the Year 1849 — *continued.*

Total of Lead. — Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. — Districts.
Tons.			Tons. cwts.	Tons. cwts.	
1156·0	Brought forward	- - - -	2,080 10	1,156 0	
393·14	Wicklow -	Glenmalure - - -	45 0	30 0	
		Luganure - - -	471 0	329 14	
		Wicklow - - -	48 10	34 0	
104·0	Waterford -	Barristown - - -	144 0	104 0	
1,653·14		Total - -	2,739 0	1,653 14	
		SCOTLAND.			
	Ayrshire - -	Afton Lead Mines - -	—	—	
151·0	Argyleshire -	Strontion Mines - -	250 15	151 0	
	Dumbartonshire	Dumbarton - - -	—	—	
806·3	Kirkcudbrightshire	Caernsmore - - -	575 0	380 0	
		Woodhead - - -	353 0	261 3	
		Black Craig - -	243 0	165 0	
	Lanarkshire -	Lead Hills Mine - -	—	—	
	Dumfrieshire -	Wanlock-head - - -	—	—	
957·3		Total - -	1,421 15	957 3	
		ISLE OF MAN.			
1,535·1	Isle of Man -	Isle of Man Mining Co. -	1,527 0	668 0	
		Laxey - - -	815 0	546 0	
		Douglas - - -	394 10	261 0	
		Sundry ores - -	90 0	60 1	
1,535·1		Total - -	2,826 10	1,535 1	

The Welsh Ticketings include also the following Foreign Ores:—

	Tons.
South Australian - - - -	574
German - - - - -	20

TABLE showing the TOTAL QUANTITY of LEAD ORE raised and LEAD smelted in the United Kingdom in 1849.

	Lead Ore.	Lead.
	Tons. cwts.	Tons. cwts.
England - - -	60,124 0	41,168 11
Wales - - -	19,711 15	13,389 0
Ireland - - -	2,739 0	1,653 14
Scotland - - -	1,421 15	957 3
Isle of Man - -	2,826 10	1,535 1
Total -	86,823 0	58,703 9

LEAD ORE and LEAD imported and exported during 1849.

IMPORTED.

	Lead Ore.	Lead.
	Tons.	Tons.
Pig and sheet - -	1,381	7,216
White Lead - - -	- -	44
Retained for home consumption -	- -	5,265

EXPORTED.

	Lead Ore.	Lead.
	Tons.	Tons.
Pig and rolled - -	181	15,227
Shot - - -	- -	1,798
Litharge - - -	- -	502
Red Lead - - -	- -	1,621
White Lead - - -	- -	1,675

1850.

COPPER.

COPPER ORE sold by PUBLIC TICKETINGS in CORNWALL and by PRIVATE CONTRACT during the year 1850.

Mines.	Ore.	Copper.				Amount.			Prod.
	Tons.	Tons.	cwts.	qrs.	lbs.	£	s.	d.	
Devon Great Consols -	17,089	1,632	5	1	13	109,989	12	6	9 1/8 1/16
Carnbrea - -	9,318	822	16	0	24	57,366	16	0	8 3/4 1/16
Par Consols - -	7,152	641	18	2	14	44,090	5	6	9
United Mines - -	9,881	638	10	3	3	43,197	10	0	6 3/8 1/16
Consolidated Mines -	7,592	576	4	2	23	40,159	16	6	7 1/8 1/16
Fowey Consols - -	6,169	542	0	3	8	37,335	12	0	8 3/4 1/16
West Caradon - -	4,049	458	4	3	19	32,646	3	6	11 1/4 1/16
South Huel Bassett -	4,409	427	14	3	8	30,826	7	0	9 3/8 1/16
Huel Seton - -	6,009	404	3	2	12	27,554	11	6	6 3/4
Tincroft - -	7,012	398	3	1	3	25,390	6	6	5 3/8 1/16
North Roskear - -	5,077	396	2	1	0	27,950	6	0	7 1/4 1/16
North Pool - -	7,048	390	4	2	19	25,617	17	0	5 1/8 1/16
Tywarnhaile - -	6,487	379	10	1	20	24,638	7	6	5 1/8
Huel Buller - -	3,345	328	3	1	21	23,409	9	6	9 1/4 1/16
South Caradon -	2,999	318	17	1	14	22,648	1	0	10 3/8
South Huel Francis -	2,678	291	3	0	19	21,388	16	6	10 1/8
Treviskey - -	2,884	285	16	0	27	20,628	10	6	9 7/8 1/16
Huel Friendship -	2,490	258	1	1	27	18,673	11	6	10 3/8
East Huel Crofty -	3,261	221	4	2	14	14,863	12	0	6 1/4 1/16
Levant - -	2,668	217	2	1	26	14,156	16	6	8 1/8
Camborne Vean -	3,046	200	6	2	9	13,613	16	0	6 1/8 1/16
South Tolgus - -	1,803	173	14	3	12	12,535	17	6	9 3/8
Alfred Consols - -	1,595	154	10	1	14	10,916	17	0	9 1/8 1/16
Bedford United Mines -	1,426	138	14	2	5	9,804	1	0	9 1/4
Perran St. George -	1,870	131	19	1	4	8,754	15	6	7 1/16
West Treasury - -	1,442	129	16	2	16	9,186	3	0	9
Treavean - -	2,680	127	19	0	13	8,042	1	6	4 1/4
Condurrow - -	1,664	113	4	0	22	7,614	0	0	6 3/8 1/16
Huel Phœnix - -	720	110	4	2	7	8,136	6	6	15 1/4 1/16
Wellington Mines -	1,034	90	6	0	15	6,177	6	0	8 1/4
Treleigh Consols -	1,355	89	7	2	7	6,105	4	6	6 1/8 1/16
Huel Comfort - -	2,263	82	9	1	12	4,649	12	0	3 3/8
Huel Mary - -	1,270	78	15	1	25	5,282	3	6	6 1/8 1/16
Mark Valley - -	1,612	75	16	3	11	4,873	12	6	4 3/8 1/16
Carried forward -	141,397	11,325	14	3	10	778,224	5	6	

Copper Ore sold by Public Tickets, &c. in Cornwall—*continued.*

Mines.	Ore.	Copper.	Amount.	Prod.
	Tons.	Tons. cwts. qrs. lbs.	£ s. d.	
Brought forward -	141,397	11,325 14 3 10	778,224 5 6	
Dolcoath - -	1,115	72 11 2 18	4,909 3 6	6 1/8
East Pool - -	1,422	70 2 1 2	4,313 18 0	4 7/8 1/16
Poldice - -	922	65 5 0 7	4,564 0 6	7 1/16
Holmbush - -	761	62 2 0 6	4,148 5 0	8 1/8
Huel Tremayne -	834	60 7 0 23	4,026 17 0	7 1/4
Huel Agar - -	866	57 5 1 15	3,839 12 6	6 5/8
Trethellan - - -	1,045	48 4 0 22	3,022 5 0	4 5/8
West Huel Seton -	639	44 11 1 5	3,007 17 6	7
Huel Henry - -	503	39 18 3 2	2,835 6 6	7 7/8 1/16
Huel Ellen - -	405	38 0 3 17	2,690 18 0	9 3/8
West Fowey Consols -	315	27 6 2 18	1,860 14 0	8 5/8 1/16
West Huel Jewell -	379	23 14 2 2	1,609 4 0	6 1/4
Charlestown United Mines	292	23 4 1 13	1,537 3 6	7 7/8 1/16
South Roskear - -	370	20 4 1 20	1,346 1 0	5 3/8 1/16
Polberro - - -	296	17 2 3 9	1,116 0 6	5 3/4 1/16
Botallack - - -	147	16 8 0 18	1,099 8 0	11 1/8
Huel Vyvian - -	242	15 19 3 5	1,061 1 6	6 5/8
South Huel Fortune -	191	15 18 0 12	1,067 9 0	8 1/4 1/16
Huel Pink - -	228	15 10 2 16	1,040 5 6	6 3/4 1/16
Hingston Downs -	75	11 17 2 0	831 5 0	15 3/4 1/16
Gonamena - -	96	11 12 1 19	853 7 0	12 1/16
Huel Maiden - -	168	11 5 2 21	763 3 0	6 3/4
East Huel Rose - -	67	9 9 2 24	734 4 6	14 1/8 1/16
St. Aubyns and Grylls -	80	8 10 1 5	578 15 0	10 5/8
Penpols regulus -	86	8 0 2 16	640 7 0	9 3/8
Huel Jewell - -	132	7 6 2 13	466 19 0	5 1/2 1/16
West Trethellan -	182	7 16 1 4	476 17 0	4 1/4 1/16
Carthew Consols -	92	6 10 0 4	379 10 6	7 1/16
Huel Busy - -	118	6 7 2 11	394 19 6	5 3/8 1/16
South Crinnis - -	75	6 3 3 5	419 0 6	8 1/4
Huel Prosper, &c. -	99	5 6 3 3	323 15 6	5 3/8 1/16
Sundries - - -	1,386	93 11 2 20	6,228 16 6	6 3/4
Total -	155,025	12,253 10 2 21	840,410 16 0	

COPPER ORE sold by PUBLIC TICKETING and by PRIVATE CONTRACT, in SWANSEA in the year 1850.

Mines.	Ore.	Copper.				Amount.			Prod.
	Tons.	Tons.	cwts.	qrs.	lbs.	£	s.	d.	
Cobre	15,905	2,964	5	0	4	233,013	9	6	18⅝
Burra Burra	3,405	1,220	1	0	17	94,476	19	6	35¾ 1/16
Bearhaven	6,137	639	6	0	12	47,687	15	0	10⅜ 1/16
Cuba	4,548	627	11	3	26	48,063	19	0	13¾ 1/16
Kapunda	949	282	10	2	17	22,199	14	0	29¾
Knockmahon	3,314	264	14	0	5	19,703	6	6	8
Copiapo	875	249	16	0	4	19,898	3	6	28½ 1/16
Chili	662	244	18	2	9	18,552	13	6	37
Santiago	1,119	206	19	3	23	16,177	1	0	18½
Kaw aw	853	110	5	3	24	8,125	6	0	12⅞ 1/16
Spanish Ore	424	37	5	3	12	2,711	17	0	8¾ 1/16
German Ore	488	34	10	1	13	2,460	4	0	7 1/16
Ballymurtagh	370	19	6	2	15	1,388	0	0	5¼
Gurtnadyne	154	16	9	1	23	1,239	9	6	10⅝ 1/16
Australian	73	15	0	0	12	1,110	8	6	20½ 1/16
South Australian	62	14	17	1	13	1,127	15	0	23⅞ 1/16
Waterloo Slag	432	14	10	1	25	838	2	6	3⅜
Llanberris	110	13	17	2	0	986	16	0	12¼ 1/16
Sydney	55	13	3	2	20	1,049	0	0	24
Lackamore	101	11	8	3	7	863	0	0	11¼ 1/16
Guildford Slag	280	10	16	1	10	737	0	0	3⅞
Cabral	87	10	12	3	14	895	0	0	12¼
Crenfuegos	115	9	12	2	14	669	17	6	8⅜
Ballinoe	59	6	17	3	18	520	18	6	11⅜ 1/16
Sand Ore	118	6	16	3	21	441	6	0	5¾ 1/16
Gloster Slag	34	6	1	3	16	471	1	0	17⅞ 1/16
Cronebane	13	5	6	1	9	396	18	6	40¾
Tigrony	13	5	5	3	14	397	10	6	40¾
Dudley Slag	156	5	1	3	10	267	5	0	3¼
Union	42	5	1	0	20	351	2	6	11⅞
Sundries	633	35	16	1	4	2,437	4	0	5⅝
Total	41,586	7,108	8	1	11	549,258	3	6	15½

Copper imported into the United Kingdom in 1850.

Ore.	Regulus.	Cast Copper.	Old Copper.	Bars, Rods, &c.	Plates, Coins, &c.	Value.
Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	£ s. d.
40,388 6	5,473 12	669 6	431 15	4,211 14	11 18	35,946 13 6

Of this Imported Copper the following countries furnished the largest quantities.

	Ore.	Regulus.	Cast Copper.	Bars and Rod.
	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.
South Australia	6,987 4	37 10	94 6	—
New South Wales	386 7	803 16	- - -	42 12
Van Diemau's Land	137 10	—	—	—
New Zealand	400 0	—	—	—
Cuba	2,231 2	—	—	—
Chili	2,250 16	3,312 14	242 10	3,084 16
Peru	1,319 10	244 2	15 0	225 1
West Coast of Africa	33 4	- - -	- - -	2 10
France	411 9	622 19	- - -	9 15
Spain	946 6	0 1	—	—
Italy	71 4	—	—	—
China	—	—	—	—

Of this quantity there was re-exported—

Ore.	Regulus.	Bricks, Pigs, &c.	Old Copper.	Bars, Rods.	Value.
Tons.cwts. qrs. lbs.	Tons.cwts. qrs. lbs.	Tons.cwts. qrs. lbs.	Tons.cwts. qrs. lbs.	Tons. cwts.qrs. lbs.	£ s. d.
20 2 1 7	136 8 1 20	254 4 2 8	20 10 3 27	580 0 2 18	31,159 0 0

British Copper exported.

Copper Ore.	Bricks and Pigs.	Coin.	Sheets, Nails, Yellow Metal.	Wire.	Wrought Copper of other Sorts.	Total.
Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.
150 10	7,733 18	7 8	13,150 7	17 17	398 2	21,307 18

TIN.

PRODUCE of TIN ORE in CORNWALL and DEVON in 1850:
10,383 Tons.

TIN imported in 1850.

Countries from which imported.	Tin.	Tin Ore and Regulus.
	Tons. cwts.	Tons cwts.
Hanseatic Towns	6 4	—
Holland	433 17	—
Belgium	4 12	—
France	12 10	—
Portugal	—	—
Spain	115 4	—
Mauritius	1 12	—
East Indies, (exclusive of Singapore and Ceylon)	347 13	0 5
Singapore	636 19	—
China, including Hong Kong	15 13	—
Victoria, Port Philip	9 9	—
United States of America	79 0	—
Chili	2 13	—
Peru	20 7	—
Total Import	1,685 11	0 5

TOTAL of TIN exported in 1850.

	Tons. cwts. qrs. lbs.
Foreign Tin	189 15 0 14
British Tin	1,588 1 2 17

LEAD.

PRODUCE of LEAD ORE and LEAD in the United Kingdom for the year 1850.

Total of Lead. — Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. — District.
Tons. cwts.	ENGLAND.		Tons. cwts.	Tons. cwts.	
	Cornwall -	Callington - -	516 0	348 18	
		Huel Mary Anne -	1,186 0	890 7	
		Huel Trelawney -	1,496 0	1,131 8	
		Huel Trehane - -	430 0	254 2	
		Tregorden - -	20 0	14 0	
		Herodscoombe - -	—	—	
		Herordsfoot - -	933 0	590 0	
		East Huel Rose -	4,206 0	2,524 3	
		Huel Penhale - -	124 0	86 15	
		Huel Golden - -	322 0	212 18	
6,782 13		North Huel Rose -	119 0	72 1	
		Cargol - - -	200 0	118 16	
		Oxnams - - -	172 0	101 3	
		Huel Rose - -	—	—	
		Holmbush - - -	200 0	119 2	
		Great Callestock Moors -	—	—	
		Huel Concord - -	—	—	
		Carthew Consols -	44 0	30 10	
		Tywarnhaile and Nancekuke	39 11	28 10	
		Huel Baddern - -	309 0	216 0	
		Pentire Glaze - -	56 10	34 0	
		Mines under 10 Tons (Sundry) - -	13 0	10 0	
	Devonshire -	Tamar - - -	977 0	561 16	
		Huel Adams - -	395 0	217 3	
		East Tamar Consols -	398 0	236 18	
1,418 17		Huel Friendship -	—	—	
		South Tamar Consols -	477 0	340 0	
		South Molton Consols -	60 0	46 0	
		South Maex - -	25 0	17 0	
	Cumberland -	Browngill - -	308 18	215 14	
		Rampgill - - -	318 2	221 12	
		Scaleburn - -	122 7	91 17	
		Carrs and Hanging Shaw	143 5	100 0	
	Governor and Company Mines.	Capel Cleugh - -	330 4	231 16	
		Small Cleugh - -	25 7	19 0	
		Middle Cleugh - -	62 2	43 10	3,132 7
3,387 19		Brown Gill Mine -	5 16	3 0	
		Guddamgill - -	47 8	33 0	
		Long Cleugh - -	2,866 0	2,001 14	
		Bentyfield Sun Vein -	9 1	6 0	
		Cowperdyke Heads -	153 7	106 3	
		Bentyfield Sun, S. E. End	265 12	185 10	
		Brigal Burn - -	102 18	70 2	
		Cowhill - - -	5 16	3 7	
		Tynebottom - -	73 13	45 7	
		Previsdale - -	17 10	10 7	
	Carried forward -		17,575 7	11,589 9	

Produce of Lead Ore and Lead in the United Kingdom for the year 1850—*continued.*

Total of Lead. — Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. — District.
Tons. cwts.			Tons. cwts.	Tons. cwts.	
	Brought forward		17,575 7	11,589 9	
	Cumberland— *continued.*	Brownley Hill - -	263 4	184 0	
		Small Mines - -	35 18	23 4	
		Blagill Vein - -	181 13	130 16	
		Carrs West of Nent Vein -	16 3	11 8	
		Black Syke - -	50 7	34 0	
		Hudgill Burn - -	128 2	91 8	
		Fore Shield - -	23 16	17 0	
		Farnbury Vein - -	8 9	7 0	
		Grassfield - -	39 18	26 0	
		Galligill Syke - -	125 15	112 13	
		Driggith - -	140 4	75 8	
		Crag Green, N. Vein -	10 6	7 0	
6,895 13		Roughtengill - -	89 0	64 0	
		Tynehead - - -	39 4	27 0	
		Force Cragg - -	8 0	5 0	
		Keswick Mine - -	175 0	107 5	
		Cross Fell Mine - -	186 0	129 0	
		Calvert - -	—	—	
		Holyfield - - -	15 0	10 0	
		North Grain Cross Vein -	0 19	—	
		Thorngill West End -	21 9	13 0	
		Well Gill Cross Vein -	70 7	51 0	
		Greensides - -	2,000 0	1,420 0	
		Nattrass Middle Vein -	13 4	10 4	
		Peat Stack Hill - -	29 5	23 0	
		Sunny Side - -	13 1	10 0	
		Slote - - -	22 5	16 0	
		Tyne Bottom - -	73 13	40 0	
		Dowke Burn West End -	20 15	14 14	
		Rodderup Cleugh West End	1,128 15	767 14	
		Dry Gill Mine - -	2 2	1 0	
		Low Berchy Bank -	18 11	13 0	
		Sundry Mines under 10 tons	31 13	21 0	
	Durham and Northumberland.	East and West Allendale and Weardale -	13,380 0	9,804 0	9,804 0
		Teesdale Mine - -	4,102 13	3,045 6	3,220 11
		Sundry Mines - -	280 8	175 5	
		Silver Tongue - -	—	—	
		Derwent Mine - -	1,770 1	1,280 0	1,280 0
		Stanhope Burn - -	412 10	280 8	
		Hollywell - -	92 0	582 0	
		Lanehead - - -	22 18	18 0	
		Aller Gill - -	16 8	11 0	
16,008 19		Bollihope - - -	12 0	9 0	
		Fallowfield - -	179 8	120 0	
		Whitefield - -	27 11	19 0	
		Settling Stones - -	550 0	375 0	
		Morley Fell - -	3 15	2 0	
		Pow Cross - -	2 9	1 15	
	Carried forward.		43,409 6	30,774 17	

Produce of Lead Ore and Lead in the United Kingdom for the Year 1850.—*continued.*

Total of Lead. Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. District.
Tons. cwts.			Tons. cwts.	Tons. cwts.	
	Brought forward		43,409 6	30,774 17	
	Durham and Northumberland—*cont.*	Captain Cleugh	20 5	14 10	
		Brandon Walls	105 5	79 0	
		Calves	23 12	18 0	
		Sundry Mines under 10 tons	9 2	6 0	
499 11	Westmoreland	Dufton and Silverband Hilton and Marton	657 2	499 11	
5,149 0	Derbyshire	Sundry Mines	7,906 3	5,149 0	
	Shropshire	Snail beach	2,626 0	1,891 0	1,891 0
		White Grit and Batholes	—	—	
1,970 0		Bog Mine	20 0	14 0	
		Rorreton	83 0	65 0	
	Somersetshire	Mendip Hills	—	—	
	Yorkshire	Swaledale and Arkendale and Hurst	5,110 6	3,475 0	3,475 0
		Wensleydale	—	—	
		Cononley	804 0	556 0	
		Grassington (including Yarnbury and Coalgrove Beck	1,766 15	1,325 0	1,325 0
		Pately District	875 0	500 0	500 0
		Kettlewell and Coniston Liberty	150 0	96 0	
		Total	63,565 16	44,462 18	
		WALES.			
	Cardiganshire	Lisburne Mines	3,345 0	2,389 0	2,389 0
		Cwm-ystwyth	801 0	572 0	
		Esgair-Llee	50 0	38 0	
		Cwm-Sebon	47 0	22 0	
		Llanfair Clydogan	88 0	67 10	
		Goginan	1,004 0	717 0	717 0
		Gogerddan Mines	35 0	23 0	
		Nant-y-creiau	—	—	
		Penrhew	20 0	14 16	
		Cefn-cwm-brwyno	13 0	—	
		Bwlch Consols	460 0	345 0	
4,768 12		Nanteos	308 0	206 10	
		Aberystwyth (small mines)	5 10	3 10	
		Llanymawn	—	—	
		Court Grange	181 0	190 0	
		Grogwinion	20 5	15 15	
		Brynarian	60 0	48 0	
		Cwm-erfin	81 0	55 10	
		Daren	15 0	10 0	
		Eisteddfodd	53 0	35 6	
		Llwyn Malees	100 0	67 10	
		Aberyfrwydd	11 0	8 5	
	Carried forward		6,697 15	4,768 12	

Produce of Lead Ore and Lead in the United Kingdom for the Year 1850—*continued.*

Total of Lead. Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. Districts.
Tons. cwts.	Brought forward		Tons. cwts. 6,697 15	Tons. cwts. 4,768 12	
9 3	Carnarvonshire -	Portmadoc - -	18 0	9 3	
	Carmarthenshire	Nant-y-Mwyn - -	1,088 1	832 17	832 17
832 17	Denbighshire -	Llangollan - -	—	—	
	Flintshire -	Talargoch { Maes-yr-erwddu, Coetia Llys } -	1,378 0	1,054 0	1,054 0
		Fronfownog - -	838 10	576 0	
		Hendre - - -	1,034 0	814 0	
		Maes-y-safn - -	1,480 0	1,069 12	1,069 12
		Pen-yr-henblas - -	811 0	616 5	
		Mold Mines - -	275 0	209 0	
		Long Rake - -	68 0	38 0	
		Milwr - -	240 0	173 0	
		Penybryn - -	12 5	7 0	
		Dingle and Deep Level -	1,027 0	758 5	
		Parry's Mines - -	20 0	15 0	
		Westminster Mines -	936 0	608 0	608 0
		Halkin Hall - -	37 0	30 0	
		Bodelwyddan - -	—	—	
		Belgrave - -	335 0	240 0	
		Bryn-gwyog - -	—	—	
8,441 5		Winster - - -	19 15	16 0	
		Jamaica - -	660 0	452 0	452 0
		Bwlchgwyn - -	30 0	26 8	
		Billings - -	14 15	7 5	
		Craigymwyn - -	25 0	19 2	
		Aberdune - -	—	—	
		Bryndigri - -	—	—	
		Axton - -	15 0	11 17	
		Pant-du - - -	28 15	20 14	
		Pant-y-celyn - -	264 0	202 0	
		Pant-y-groes - -	21 5	15 13	
		Pant-y-pwlldwr - -	15 0	11 2	
		Pant-y-ffryth - -	216 0	163 9	
		Strong Croft - -	—	—	
		Talacre - - -	865 0	669 13	669 13
		Lloe - - -	655 0	501 0	
		Fori - - -	15 5	11 15	
		Sundries (under 10 tons) -	139 0	106 5	
	Montgomeryshire	Llangynnog - -	—	—	
		Cae-conroy - -	117 0	88 18	
		Rhos-wydol - -	98 0	75 13	
		Dwn-gwm or Dyfngwm -	24 0	17 18	
		Craig Rhiwarth - -	26 10	20 0	
		Bryntail - -	116 10	28 0	
772 9		Gorn - - -	51 15	39 0	
		Machynlleth, including Delife - -	653 5	503 0	503 0
		Nantmelyn - -	-	—	
		Pen-y-clyn - -	776 0	—	
	Carried forward		21,026 6	14,825 6	

Produce of Lead Ore and Lead in the United Kingdom for the Year 1850.—*continued.*

Total of Lead. Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. District.
Tons. cwts.			Tons. cwts.	Tons. cwts.	
	Brought forward		21,026 6	14,825 6	
	Merionethshire -	Barmouth, Port of -	—	—	
		Cowarch - - -	—	—	
		Tyddyngwladus - -	—	—	
51 5		Dolgelly - -	—	—	
		Eagles Rock - -	67 0	51 5	
		Bwlch-y-plwm - -	—	—	
		Total -	21,093 6	14,876 11	
		IRELAND.			
	Clare - -	Kilbricken - -	—	—	
		Ballyhicky - -	—	—	
		Castleblayney - -	—	—	
14 8		Arklow - - -	18 10	14 8	
	Down - -	Newtownards - -	1,200 0	671 0	671 0
810 19		Conligg - - -	243 1	139 19	
13 9	Cork - -	Bantry - -	22 15	13 9	
283 14	Tipperary -	Shallee - - -	473 0	283 14	283 14
	Monaghan -	Bond and Newry -	—	—	
	Wicklow -	Glenmalure - -	200 0	125 0	
		Luganure - -	522 0	364 0	364 0
541 11		Wicklow - - -	66 0	52 11	
82 0	Wexford -	Barristown - -	150 0	82 0	
		Total -	2,895 6	1,746 1	
		SCOTLAND.			
	Ayrshire -	Afton Lead Mines -	—	—	
226 10	Argyleshire -	Strontian Mines - -	290 5	226 10	
21 0	Dumbartonshire	Dumbarton - -	35 0	21 0	
	Kirkcudbright-shire.	Cairnsmore - -	480 0	352 0	352 0
		Woodhead - -	385 0	287 16	
742 0		Black Craig - -	151 0	102 11	
43 15	Perthshire -	Breadalbane - -	60 0	43 15	
375 10	Lanarkshire -	Lead Hills Mine -	695 0	375 10	
	Dumfriesshire -	Wanlock Head - -	1,021 0	715 3	
		Total -	3,117 5	2,124 5	
		ISLE OF MAN.			
	Isle of Man -	Isle of Man Mining Company	1,340 0	586 3	586 3
		Laxey - - -	810 0	615 16	
		Douglas - -	—	—	
		South Manx - -	25 0	17 0	
		Total -	2,175 0	1,218 19	

Produce of Lead Ore and Lead in the United Kingdom for the Year 1850—*continued.*

The Welsh Ticketings include also the following Foreign ores:—

	Lead Ore.	Lead.
	Tons. cwts.	Tons. cwts.
South Australian -	127 0	92 14
German - - -	30 0	15 0
Arkansas - -	38 0	27 15
Oporto - - -	11 15	8 11
Total -	206 15	144 0

TABLE showing the TOTAL QUANTITY of LEAD ORE raised and smelted in the United Kingdom in 1850.

	Lead Ore.	Lead.
	Tons. cwts.	Tons. cwts.
England - -	63,565 16	44,462 18
Wales - - -	21,093 6	14,876 11
Foreign Ores - -	206 15	144 0
Ireland - -	2,895 6	1,746 1
Scotland - - -	3,117 5	2,124 5
Isle of Man - -	2,175 0	1,218 19
Total -	93,053 8	64,572 14

LEAD ORE and LEAD imported and exported during 1850.

IMPORTED.

	Tons. cwts.
Lead Ore - - -	1,380 14
Pig and Sheet Lead -	7,215 19
White Lead - - -	43 5
Retained for home consumption, principally Pig Lead -	5,265 12

EXPORTED.

	Tons. cwts.
Lead Ore - - -	180 0
Pig and Rolled Lead -	15,227 8
Shot - - - -	1,798 11
Litharge - - -	502 9
Red Lead - - -	1,621 0
White Lead - - -	1,675 13

1851.

COPPER.

COPPER ORES sold by PUBLIC TICKETINGS in CORNWALL, and by PRIVATE CONTRACT during the year 1851.

Mines.	Ore.	Copper.	Amount.	Prod.
	Tons.	Tons. cwts. qrs. lbs.	£ s. d.	
Devon Great Consols -	18,921	1,708 11 2 25	111,082 0 6	9
Par Consols - -	6,986	660 2 0 24	44,353 3 0	9⅜ 1/16
Carnbrea - -	7,663	632 8 1 21	42,181 6 6	8¼
United Mines - -	8,181	585 0 3 20	39,001 18 6	7⅛
Huel Buller - -	5,747	489 16 3 7	33,913 17 6	8½
Huel Basset - -	5,442	487 17 3 18	33,324 7 6	8⅞ 1/16
Tincroft - -	7,827	474 0 0 15	29,706 6 0	6 1/16
West Caradon - -	4,128	443 0 3 23	30,329 17 0	10¾
Fowey Consols -	5,203	442 3 3 13	28,967 8 6	8½
Consolidated Mines -	5,661	407 15 0 24	27,285 5 6	7⅛ 1/16
North Roskear -	4,548	376 6 2 5	25,844 13 6	8½
Huel Seton - -	5,471	372 14 1 25	24,708 7 6	6¾ 1/16
North Pool - -	5,914	334 0 3 11	21,078 10 6	5⅝
Tywarnhaile - -	5,649	321 4 2 24	20,304 9 0	5⅝ 1/16
South Caradon -	2,818	296 9 1 21	20,208 0 6	10½
South Huel Francis -	2,709	291 19 3 20	20,351 18 0	10¾
Alfred Consols -	2,819	270 19 2 0	19,210 14 0	9⅝
Huel Friendship -	2,474	238 4 3 19	16,408 9 0	9⅝
Perran St. George -	3,753	230 15 2 10	14,375 4 0	6½
Treviskey - -	2,459	214 2 1 11	14,724 2 0	8⅝ 1/16
South Tolgus - -	2,427	208 16 3 2	14,323 7 0	8⅝
Bedford United -	1,700	154 15 1 27	10,341 13 0	9½
East Huel Crofty -	2,267	152 15 3 19	10,033 19 6	6⅔
Huel Phœnix - -	962	147 0 2 22	10,501 13 6	15¼
Condurrow - -	1,707	121 10 0 23	8,057 3 0	7⅛
Camborne Vean -	2,067	120 3 1 5	7,618 18 0	5⅞ 1/16
Levant - -	1,539	118 2 1 10	7,350 5 6	7⅝ 1/16
East Pool - -	2,050	106 16 1 20	6,502 10 6	5½ 1/16
Holmbush - -	1,188	100 6 3 11	6,731 12 0	8⅜ 1/16
Marke Valley - -	1,701	91 0 2 19	5,923 10 6	5⅜
Tresavean - -	1,850	86 1 3 15	5,100 19 0	4⅝
Treleigh Consols -	1,137	81 15 3 12	5,451 7 0	7⅛ 1/16
West Treasury -	857	73 16 3 26	5,104 14 0	8⅝
Huel Agar - -	806	70 7 0 17	4,872 17 0	8¾
Dolcoath - -	801	55 8 0 14	3,625 18 0	6⅞ 1/16
Carried forward -	137,432	10,966 15 0 18	728,900 6 0	

Copper Ores sold by Public Ticketings, &c. in Cornwall—*continued.*

Mines.	Ore.	Copper.				Amount.			Prod.
	Tons.	Tons.	cwts.	qrs.	lbs.	£	s.	d.	
Brought forward -	137,432	10,966	15	0	18	728,900	6	0	
Huel Comfort - -	1,573	52	16	1	7	2,698	18	0	3⅝
Poldice - -	703	48	5	2	8	3,182	19	6	6⅞
West Fowey Consols -	469	39	14	3	9	2,596	9	0	8½
West Seaton - -	532	36	18	3	18	2,459	8	0	6⅞ ⅛
Huel Mary (Redruth) -	513	30	19	3	15	1,969	6	0	6
Huel Ellen - -	392	30	8	2	15	2,049	5	0	7¾
Wellington Mines -	430	30	0	3	15	1,946	13	6	7
West Providence -	194	28	16	3	2	2,070	11	0	14⅞
Huel Tremayne -	525	28	9	1	25	1,724	1	0	5⅝ ⅛
Polberro - -	578	27	12	2	15	1,666	2	0	4¾
West Huel Jewell -	327	26	7	0	19	1,814	11	0	8⅛
Trethellan - -	523	25	12	1	18	1,535	18	6	4⅞
Botallack - -	212	21	18	3	16	1,457	14	0	10⅜
East Huel Leisure -	355	17	1	2	18	993	18	0	4¾ ⅛
Huel Unity Consols -	306	16	13	3	23	1,035	0	0	5⅜ ⅛
Cooks Kitchen -	226	16	5	0	18	1,068	16	6	7⅛ ⅛
Gonamena - -	159	16	3	3	27	1,112	8	0	10⅛ ⅛
Pendarves Consols -	258	15	6	0	26	971	14	0	5⅞ ⅛
Huel Clifford - -	174	14	2	1	9	964	4	6	8⅛
Hingston Downs -	127	13	19	2	2	978	0	0	11
Huel Henry - -	154	13	2	0	9	899	13	6	8⅛
Callington Killibray -	147	11	9	1	25	754	11	6	7¾
East Huel Rose -	93	11	1	0	27	789	10	6	11⅞
Huel Maiden - -	134	10	14	2	5	728	13	6	8
Crane and Bejawsa -	103	10	8	0	19	739	14	0	10⅛
Boscundle - -	57	9	13	3	5	686	17	0	17
St. Aubyns and Grylls -	110	9	8	3	27	639	15	0	8½ ⅛
Trelyon Consols -	100	9	1	3	7	635	1	6	9⅛
Huel Busy - -	173	8	18	3	15	538	4	6	5⅛ ⅛
Copper Bottom -	104	8	15	2	4	610	5	0	8⅜ ⅛
Huel Gorlana - -	93	8	3	3	2	571	17	0	8¾ ⅛
Hallamanning - -	123	8	2	1	5	552	6	6	6⅜ ⅛
West Alfred Consols -	130	7	15	0	13	502	0	0	5⅞ ⅛
Huel Jewell - -	114	7	7	3	19	481	16	6	6⅛
Hawks point - -	136	7	4	2	1	456	3	6	5¼ ⅛
Carried forward -	147,779	11,645	18	2	2	772,782	13	0	

Copper Ores sold by Public Ticketings, &c. in Cornwall—*continued.*

Mines.	Ore.	Copper.				Amount.			Prod.
	Tons.	Tons.	cwts.	qrs.	lbs.	£	s.	d.	
Brought forward -	147,779	11,645	18	2	2	772,782	13	0	
Carthew Consols -	113	7	1	2	12	443	12	0	6¼
Huel Mary (Bodmin) -	118	6	14	0	2	427	0	0	5⅝ 1/16
Trannack and Boscence -	59	6	10	3	5	456	19	0	11⅛
Providence Mines -	141	6	10	1	26	362	10	0	4⅝
Carvannel - -	102	6	10	0	8	416	18	6	6⅝
South Crinnis - -	95	5	6	2	20	302	4	0	5⅝
South Huel Speed -	105	5	4	2	6	319	5	6	5
East Godolphin -	96	5	2	1	24	311	13	6	5½ 1/16
Sundries (under 5 Tons Copper - -)	1,772	112	9	1	25	7,124	13	0	6½ 1/16
Total -	150,380	11,807	8	2	18	782,947	8	6	

Copper Ore sold at Swansea by Public Ticketings and by Private Contract in the year 1851.

Mines.	Ore.	Copper.				Amount.			Prod.
	Tons.	Tons.	cwts.	qrs.	lbs.	£	s.	d.	
Cobre - - -	14,724	2,851	8	3	2	220,619	12	6	19⅜
Bearhaven - - -	6,969	710	5	3	27	53,810	0	6	10⅛ 1/16
Cuba - - - -	2,955	508	1	0	9	39,122	1	0	17⅛ 1/16
Kapunda - - -	868	304	6	3	7	24,420	4	0	35 1/16
Burra Burra - -	829	299	15	0	16	23,949	15	6	37⅛ 1/16
Knockmahon - -	3,624	290	11	1	18	21,573	7	6	8
Santiago - -	2,036	280	5	0	7	21,353	3	0	13¾
Chili - - - -	421	160	10	0	11	12,612	9	0	38⅛
Kawaw - - -	961	138	17	0	20	10,561	7	0	14⅜ 1/16
Copiapo - - -	406	88	15	2	5	6,919	16	0	21⅞
Spanish Ore - - -	597	72	2	3	12	5,607	13	6	12 1/16
West Kaw aw - -	423	34	5	3	18	2,492	7	0	8⅛
Montreal - - -	219	31	15	2	21	2,444	8	6	14⅛
Havannah - - -	161	23	13	1	13	1,930	4	0	14⅝ 1/16
Tuneklillo - - -	128	23	0	3	24	1,823	4	0	18
German Ore - - -	193	17	0	1	26	1,254	3	6	8¾ 1/16
Lackamore - - -	204	16	3	2	4	1,218	8	6	7⅞ 1/16
Waterloo Slag - - -	345	15	7	0	23	987	18	0	4⅜ 1/16
Sydney - - -	68	14	11	2	25	1,194	11	6	21⅛
Australian - - -	65	14	7	2	14	1,118	0	0	22⅛
South Australian - -	48	11	8	0	0	890	8	0	23⅜
Port Lincoln - - -	52	11	4	1	0	871	0	0	21⅛
New Zealand - - -	96	11	0	1	14	848	0	6	11⅜ 1/16
Paringo - - -	40	10	0	0	0	785	0	0	25
Gyfron - - -	49	8	19	2	9	713	6	0	18⅜
Ballinoe - - - -	97	8	16	1	26	542	0	0	9 1/16
Ballymurtagh - - -	104	6	14	1	13	485	6	0	6⅜ 1/16
Dudley Slag - - -	137	5	2	3	13	331	6	6	3¼
Aberdovey - - -	65	5	1	1	14	375	2	6	7¾
Sundries - - -	357	41	6	3	18	3,098	19	0	11⅛ 1/16
Total -	37,241	6,015	0	2	17	463,953	0	0	14⅝

Copper imported into the United Kingdom in 1851.

Ore.	Regulus.	Cast Copper.	Old Copper.	Bars, Rods, &c.	Plates, Coins.	Value.
Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	£ s. d.
35,683 18	6,442 5	1,093 1	524 0	3,950 13	22 13	30,073 13 9

Of this Imported Copper the following countries furnished the largest quantities.

	Ore.	Regulus.	Cast Copper.	Bars and Rods.
	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.
South Australia	4,128 1	185 11	760 0	218 14
New South Wales	951 7	929 2	3 0	34 16
Victoria	615 18	—	9 10	—
Van Dieman's Land	199 4	—	—	—
New Zealand	209 18	—	—	—
British North American Colonies	719 8	—	—	—
Cuba	20,825 8	—	—	—
Chili	3,149 11	4,901 15	212 18	3,022 16
Peru	1,175 19	260 4	—	148 14
Bolivia	245 0	—	—	—
West Coast of Africa	11 13	—	—	—
France	1,024 5	19 11	52 10	17 14
Spain	1,082 1	65 8	—	2 7
Algeria	879 12	—	—	—
Holland	202 8	—	13 14	8 8

Of this quantity there was re-exported—

Ore.	Regulus.	Cast Copper.	Old Copper.	Bars, Rods, &c.	Plates and Coins.	Value.
Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	£ s. d.
190 13	8 0	570 0	25 9	715 17	8 18	24,779 0 0

British Copper exported.

Ore.	Bricks, Pigs, &c.	Coin.	Sheets, Nails, Yellow Metal.	Wire.	Wrought Copper of other Sorts.	Total.
Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.
1 3	5,612 5	75 10	11,050 13	35 15	781 8	17,555 11

TIN.

PRODUCE of TIN ORE in CORNWALL and DEVON in 1851:

9,455 Tons.

TIN imported in 1851.

Countries from which imported.	Tin. Tons.	cwts.	Tin Ore and Regulus. Tons.	cwts.
Hanseatic Towns	61	6	—	
Holland	952	15	—	
France			5	0
Spain	54	10	—	
Egypt	0	2	—	
East Indies (exclusive of Singapore and Ceylon)	459	16	—	
Singapore	805	15	—	
China (including Hong Kong)	2	6	—	
United States of America	178	6	—	
Chili	1	8	—	
Peru	70	17	—	
Total Import	2,587	1	5	0

TIN exported in 1851.

	Tons.	cwts.	qrs.	lbs.
Foreign Tin	245	9	0	0
British Tin	1,011	0	0	0

LEAD.

PRODUCE of LEAD ORE and LEAD in the UNITED KINGDOM for the Year 1851.

Total of Lead. — Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. — District.
Tons. cwts.		ENGLAND.	Tons. cwts.	Tons. cwts.	
	Cornwall -	Callington - -	597 9	417 18	
		Huel Mary Anne -	1,265 0	948 14	
		Huel Trelawney -	1,112 7	840 7	
		Huel Trehane - -	414 0	285 15	
		Tregorden - -	15 0	7 0	
		Herodscoombe - -	—	—	
		Herodsfoot - -	833 0	624 0	
		East Huel Rose -	3,192 19	2,234 0	2,234 0
		North Huel Rose -	354 0	214 3	
		Cargol - -	309 19	184 18	
		Oxnams Land - -	70 11	44 15	
		South Cargol - -	42 1	30 0	
		Charity Lands - -	38 15	25 0	
		Dean and Chapter Lands -	6 11	5 0	
		Huel Penhale - -	65 0	42 1	
6,709 3		Huel Golden - -	429 0	284 5	
		Huel Rose - -	—	—	
		Holmbush - -	30 0	17 15	
		Great Callestock Moors -	—	—	
		Huel Concord - -	—	—	
		Carthew Consols -	33 0	23 5	
		Great Huel Baddern -	346 0	244 9	
		Pentire Glaze - -	201 0	119 18	
		Nancekuke - -	159 12	116 0	
	Devonshire -	Tamar - -	1,017 18	585 5	585 5
		Huel Adams - -	230 0	126 7	
		East Tamar Consols -	384 0	286 3	
1,628 16		Huel Friendship -	3 3	2 2	
		South Tamar Consols -	668 0	474 0	474 0
		South Molton Consols -	—	—	
		South Maex - -	—	—	
		Huel Exmouth - -	230 0	141 19	
		Huel Ex - -	18 0	13 0	
	Cumberland -	Browngill - -	191 10	137 13	
		Rampgill - -	267 8	187 15	
		Scaleburn - -	83 0	63 7	
		Carrs and Hanging Shaw -	154 0	107 1	
		Capel Cleugh - -	272 0	191 4	
	Governor and Company Mines.	Small Cleugh - -	74 4	54 16	2,551 8
		Middle Cleugh - -	77 13	54 12	
		Guddamgill - -	67 17	46 15	
		Long Cleugh - -	2,052 14	1,435 9	1,435 9
		Bentyfield Sun Vein -	39 16	28 0	
		Cowperdyke Heads -	202 7	141 0	
		Tynebottom - -	61 19	37 14	
		Priorsdale - -	9 19	6 2	
	Carried forward		15,620 12	10,829 7	

Produce of Lead Ore and Lead in the United Kingdom for the Year 1851—*continued.*

Total of Lead. Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. District.
Tons. cwts.	Brought forward		Tons. cwts. 15,620 12	Tons. cwts. 10,829 7	
	Cumberland—*cont.*	Bentyfield Sun, S. E. End	88 17	60 0	
		Brigal Burn	133 0	96 7	
		Cow Gap	0 11	0 8	
		Dowpot Syke	0 8	0 6	
		Fore Shield	1 14	1 2	
		Flow Edge	1 13	1 2	
		Gutter Gill	0 10	0 7	
		Brownlow Hill	280 0	195 3	
		Blagill Vein	65 2	46 16	
		Carrs West of Nent Vein	7 18	6 0	
		Black Syke	45 2	30 0	
		Hudgill Burn	138 12	100 3	
		Farnbury Vein	—	—	
		Grassfield	30 16	20 10	
		Gilligill Syke	89 10	80 1	
		Crag Green, N. Vein	25 5	18 0	
		Roughtongill	—	—	
		Tyne Head	48 6	34 0	
		Force Cragg	—	—	
		Keswick Mine	102 10	73 10	
6,325 15		Cross Fell Mine	166 16	124 0	
		Greenside	2,000 0	1,420 0	1,420 0
		Holyfield	19 0	12 13	
		North Grain Cross Vein	—	—	
		Thorngill West End	33 16	20 1	
		Well Gill Cross Vein	50 8	37 3	
		Nattrass Middle Vein	14 5	11 10	
		Peat Stack Hill	20 8	16 9	
		Sunny Side	1 1	0 15	
		Slote	0 13	0 9	
		Tyne Bottom	61 12	33 10	
		Dowke Burn West End	1 4	1 0	
		Rodderup Cleugh West End	1,210 6	823 0	823 0
		Low Birchy Bank	29 16	20 10	
		Cald Beck Mine	659 4	423 0	
		Wood End	13 0	8 0	
		Smittergill Foot Mine	5 19	4 10	
		Anna Clough	60 0	45 0	
		Nattrass North Vein	1 17	1 6	
		Thorngill East Vein	3 1	2 0	
		Park Grove Sun Vein	10 10	8 2	
		Dry Burn	1 1	0 15	
		Howgill Syke	13 15	11 0	
		Windy Brow North Vein	1 2	0 16	
		Claregillhead	11 11	9 0	
		Smittergill Head Mine	42 0	31 10	
		Clargill Burn	1 5	1 0	
		Gold Scope	14 10	11 0	
	Carried forward		21,128 6	14,671 1	

Produce of Lead Ore and Lead in the United Kingdom for the Year 1851—*continued.*

Total of Lead. Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. District.
Tons. cwts.			Tons. cwts.	Tons. cwts.	
	Brought forward		21,128 6	14,671 1	
	Durham and Northumberland.	East and West Allendale and Weardale	13,560 0	9,977 0	9,977 0
		Teesdale Mines	5,235 6	3,769 1	3,769 1
		Silver Tongue	—	—	
		Derwent Mines	1,600 0	1,200 0	1,200 0
		Stanhope Burn	340 5	231 1	
		Hollywell	26 18	18 0	
15,488 12		Lanehead	27 3	20 0	
		Allergill	9 2	6 10	
		Bollihope	10 5	7 0	
		Fallowfield	162 9	122 0	
		Whitefield	20 18	15 0	
		Captain Cleugh	53 11	38 0	
		Brandon Walls	108 0	78 0	
		Calves	8 9	6 0	
		Mellowburry	1 8	1 0	
395 14	Westmorland	Dufton and Silverband, Hilton, Marton, and Hardshins	591 9	395 14	
5,100 0	Derbyshire	Sundry Mines	7,900 0	5,100 0	5,100 0
	Shropshire	Snail Beach	2,837 0	2,127 0	
		Bat Holes	517 0	387 14	2,127 0
3,165 8		Bog Mine	—	—	
		Rorington	83 0	65 0	
		White Grit	781 0	585 14	
	Somersetshire	Mendip Hills	—	—	
	Yorkshire	Swaledale, Arkendale, and Hurst	5,000 0	3,472 0	3,472 0
		Wensleydale	696 0	500 0	
		Cononley	733 10	520 10	
6,232 14		Grassington (including Yarnbury and Coalgrove Beck)	1,489 18	997 9	997 9
		Pately District	981 7	652 15	625 15
		Kettlewell and Coniston Liberty	200 0	140 0	
		Total	64,102 4	45,103 10	
		Wales.			
	Cardiganshire	Lisburne Mine	3,406 3	2,753 2	2,753 2
		Cwm-ystwyth	789 2	637 7	637 0
		Esgair-Lee	89 6	68 1	
		Cwm-sebon	17 17	8 15	
		Llanfair Clydogan	—	—	
		Goginan	845 9	675 3	
	Carried forward		5,147 17	4,142 8	

Produce of Lead Ore and Lead in the United Kingdom for the year 1851—*continued.*

Total of Lead. Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. District.
Tons. cwts.			Tons. cwts.	Tons. cwts.	
	Brought forward		5,147 17	4,142 8	
	Cardiganshire—*continued.*	Llower cwm bach	1 14	1 5	
		Llettyhen	22 19	17 5	
		Nant-y-creiau	—	—	
		Penrhew	3 0	20 5	
		Cefn-cwm-brwyno	13 19	11 11	
		Bwlch Consols	445 0	367 1	
		Nanteos	459 0	338 2	
		Llryn Malers	59 13	45 0	
		Court Grange	279 0	216 3	
		Grogwinion	44 10	35 0	
		Brynarian	95 0	76 0	
		Cwm-erfin	187 19	140 14	
		Daren	82 14	53 19	
		Aberyfrwydd	—	—	
		Esgair Hir	5 0	3 10	
		Grogwinion	22 0	16 10	
5,809 7		Cwm Darren	20 9	14 14	
		Cambrian	40 0	26 0	
		Baramore	38 0	28 0	
		Bronfloyd	12 0	11 0	
		Cefngyntle	13 5	10 0	
		Craigymwyn	23 0	17 0	
		Alty Crib	166 19	218 0	
	Carnarvonshire	Portmadoc	—	—	
596 0	Carmarthenshire	Nant-y-Mwyn	771 0	596 0	596 0
	Denbighshire	Llangollan	—	—	
	Flintshire	Talargoch { Maes-yr-erwddu / Coetia Llys }	1,331 0	1,018 1	1,018 1
		Fronfownog	—	—	
		Hendre	392 0	309 7	
		Maes-y-safn	1,074 0	840 0	
		Pen-yr-henblas	667 0	504 3	
		Long Rake	85 0	48 0	
		Milwr	235 0	172 0	
		Penybryn	41 5	24 10	
		Dingle and Deep Level	989 0	730 1	
		Parry's Mines	—	—	
		Westminster Mines	1,651 0	1,071 7	1,071 7
		Halkin Hall	67 15	55 2	
		Bodelwyddan	—	—	
		Belgrave	46 0	33 2	
		Bryn-gwynog	—	—	
		Winster	—	—	
		Orsedd	13 0	9 2	
		Carrigboeth	14 0	10 0	
		Jamaica	399 0	300 0	
		Bwlchgwyn	235 0	211 1	
	Carried forward		15,193 18	11,741 3	

Produce of Lead Ore and Lead in the United Kingdom for the Year 1851—*continued.*

Total of Lead. Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. District.
Tons. cwts.			Tons. cwts.	Tons. cwts.	
	Brought forward		15,193 18	11,741 3	
	Flintshire—*cont.*	Billings	17 15	9 0	
		Craigwen	12 0	5 2	
		Aberdune	—	—	
		Bryndigri	—	—	
		Axton	61 0	48 16	
		Pant-du	—	—	
		Pant-y-celyn	59 0	45 7	
		Pant-y-groes	—	—	
		Pant-y-pwlldwr	34 10	25 6	
		Pant-y-ffryth	141 0	107 1	
		Strong Croft	—	—	
		Talacre	336 0	260 2	
		Lloc	364 0	278 8	
6,783 13		Maery-eafu	10 5	7 0	
		Merllyn	381 0	266 14	
		Panty-mwym or Mold Mines	362 5	271 19	271 19
		Plantation	15 0	10 10	
		Waste	18 0	12 12	
		Sundries under 10 Tons	133 5	100 0	
	Montgomeryshire	Llangynnog	—	—	
		Cae-conroy	150 0	114 2	
		Rhos-wydol	49 0	38 0	
		Dwn-gwm or Dyfngwm	45 0	33 14	
		Craig Rhiwarth	—	—	
		Bryntail	384 0	277 0	
1,556 8		Gorn	47 5	36 0	
		Machynlleth, including Delife	1,003 0	772 12	722 12
		Nantmelyn	—	—	
		Pen-y-clyn	407 1	285 0	
68 8	Merionethshire	Barmouth, Port of	—	—	
		Cowarch	—	—	
		Tyddyingbuddel	14 0	9 16	
		Dolgelly	—	—	
		Eagles Rock	76 0	58 12	
		Bwlch-y-plwm	—	—	
		Total	19,314 4	14,813 16	
		IRELAND.			
	Clare	Kilbricken	—	—	
		Ballyhicky	—	—	
	Armagh	Castleblayney	—	—	
894 13	Down	Newtownards	1,643 11	894 13	894 13
		Conlig	191 0	—	
	Cork	Bantry	—	—	
	Carried forward		1,834 11	894 13	

Produce of Lead Ore and Lead in the United Kingdom for the year 1851—*continued.*

Total of Lead. Counties.	County.	Mines.	Lead Ore Returns.	Lead Returns.	Tons of Lead. District.
Tons. cwts.			Tons. cwts.	Tons. cwts.	
	Brought forward		1,834 11	894 13	
42 0	Galway - -	Glengola - - -	60 0	42 0	
279 4	Tipperary	Shallee - - -	465 5	279 4	
	Monaghan -	Bond and Newry -	—	—	
	Wicklow -	Glenmalure - -	105 0	65 10	
613 10		Luganure - -	740 0	534 0	534 0
		Wicklow - -	—	—	
		Arklow - - -	18 0	14 0	
	Wexford -	Barristown - -	—	—	
		Total -	3,222 16	1,829 7	
		Scotland.			
	Ayrshire - -	Afton Lead Mines -	—	—	
225 0	Argyleshire -	Strontian Mines - -	288 0	225 0	
	Dumbartonshire	Dumbarton - -	—	—	
894 4	Kircudbright-shire.	Cairnsmore - -	481 0	353 0	
		Woodhead - -	401 0	299 0	
		Black Craig - -	355 0	242 4	
	Perthshire -	Breadalbane - -	—	—	
320 0	Lanarkshire -	Lead Hills Mine -	600 0	320 0	
500 0	Dumfrieshire -	Wanlock Head - -	988 0	701 0	500 0
		Total -	3,113 0	2,140 4	
		Isle of Man.			
	Isle of Man -	Isle of Man Mining Company - -	1,660 0	718 1	718 1
		Laxey - - -	900 0	684 9	684 9
		Douglas - - -	—	—	
		South Manx - -	—	—	
		Total -	2,560 0	1,402 10	

The Welsh ticketings include also the following foreign ores:—

	Lead Ore.	Lead.
	Tons. cwts.	Tons. cwts.
South Australian -	190 0	138 11
German - -	—	—
Arkansas -	22 10	16 2
Oporto - - -	—	—
Total -	212 10	154 13

TABLE showing the TOTAL QUANTITY of LEAD ORE raised and smelted in the United Kingdom in 1851.

	Lead Ore.	Lead.
	Tons. cwts.	Tons. cwts.
England - -	64,102 4	45,103 9
Wales - - -	19,314 4	14,813 16
Foreign Ores - -	212 10	154 13
Ireland - -	3,222 16	1,829 7
Scotland - - -	3,113 3	2,140 4
Isle of Man - -	2,560 0	1,402 10
Total - -	92,524 14	65,443 19

LEAD ORE and LEAD imported and exported during 1851.

IMPORTED.

	Tons. cwts.
Lead Ore - - - -	2,790 0
Pig and Sheet Lead - - -	*14,591 0
White Lead - - -	47 0
Lead re-exported - - -	6,355 0
Retained for home consumption, principally Pig Lead - - - -	10,326 0

EXPORTED.

	Tons. cwts.
Lead Ore - - - -	133 0
Pig and Rolled Lead - - -	18,029 0
Shot - - - - -	1,459 0
Litharge - - - -	446 0
Red Lead - - - -	1,499 0
White Lead - - - -	1,339 0

* The Lead imported from Spain alone amounted to 14,402 Tons.

SILVER.

Estimate of Silver produced from the Mines of Great Britain and Ireland in 1851.

The produce of Silver stated must be considered as an approximation only, founded upon a general acquaintance with the Mines of the different districts, the only method by which an estimate could be made, and is liable to correction. For this Return the Office is indebted to Mr. John Taylor.

The quantities of Lead in each district are deduced from the foregoing Tables the mean of several years being taken.

Mines producing Lead.	Quantities of Pig Lead in each per annum.	Supposed proportion of Silver in each Ton of Lead.	Number of Ounces of Silver from each district.	Value at Five Shillings per ounce.
	Tons.	Ounces.		£
Cornwall	7,304	35	255,640	63,910
Devonshire	1,026	40	41,040	10,260
Cumberland	5,702	9	51,318	12,829
Durham, Westmorland, and Northumberland	13,233	12	158,796	39,699
Derbyshire	4,250	None.	—	—
Shropshire	2,769	None.	—	—
Yorkshire	5,223	None.	—	—
Cardiganshire, Carnarvonshire, and Carmarthenshire	3,492	15	52,380	13,095
Flintshire and Denbighshire	8,122	7	56,854	14,213
Montgomeryshire and Merionethshire	679	6	4,074	1,018
Ireland	1,380	10	13,800	3,450
Scotland	822	8	6,576	1,644
Isle of Man	1,699	20	33,980	8,495
	55,701		674,458	168,614

Estimate of Lead and Silver annually imported into Great Britain.

Spanish Lead imported in 1850	6,210	Tons.
Other Lead	1,005	„
	7,215	„
Lead Ore imported in 1850, 1,380 Tons =	1,120	„ of Lead.
	8,335	„
The average content of Silver may be estimated at	20	Oz. per Ton.
	166,700	Ounces.
Valued at 5s. per Ounce	£41,675	

In addition to the Silver obtained from Lead, there is now a large importation of Silver Ores, and argentiferous Copper Ores from Chili, Peru, and other parts of South America. The value of the Silver extracted is probably not less than £150,000

1852.

COPPER.

COPPER ORES sold by PUBLIC TICKETINGS in CORNWALL and by PRIVATE CONTRACT during the year 1852.

Mines.	Ore.	Copper.	Amount.	Produce.
	Tons.	Tons. cwts. qrs. lbs.	£ s. d.	
Devon Great Consols -	20,802	1,659 2 0 12	134,224 1 0	8
United Mines - -	10,233	646 3 1 6	55,462 9 6	6 1/4 1/16
Huel Buller - -	9,310	632 16 0 2	53,257 15 6	6 3/4
Par Consols - -	5,692	527 15 3 2	43,818 4 6	9 1/4
Tincroft - -	9,559	515 8 2 5	39,867 7 0	5 3/8
Huel Basset - -	5,966	503 13 0 8	42,933 11 6	8 3/8 1/16
Carnbrea - -	6,616	472 5 1 6	39,049 5 6	7 1/8
West Caradon - -	4,048	407 5 1 11	34,812 19 6	10 1/16
Fowey Consols - -	4,622	380 11 3 3	30,853 6 0	8 1/4
Alfred Consols -	3,892	347 3 1 21	29,561 3 0	8 7/8 1/16
Consolidated Mines -	5,147	344 19 2 7	28,526 14 0	6 5/8 1/16
Huel Seton - -	5,286	314 10 3 23	25,347 13 0	5 7/8 1/16
North Pool - -	5,196	292 3 0 4	23,280 12 6	5 5/8
South Caradon - -	2,834	276 15 1 15	23,965 14 6	9 3/4
North Roskear - -	3,202	247 8 0 10	20,466 10 6	7 3/4
South Frances - -	2,506	225 12 3 2	19,150 14 0	9
South Tolgus - -	2,521	210 8 3 16	18,605 15 0	8 1/4 1/16
Huel Friendship East -	2,048	198 14 2 21	17,263 3 6	9 5/8 1/16
Perran St. George -	3,775	198 12 3 11	15,385 15 0	5 1/4
Hallamanning, &c. -	2,947	197 3 3 23	16,952 1 6	6 5/8 1/16
North Basset - -	2,638	181 6 0 12	15,275 10 0	6 7/8
Phœnix Mine - -	1,338	156 16 2 22	14,002 11 0	11 3/4
Bedford United -	1,871	141 18 2 21	11,986 0 0	7 1/8 1/16
Treviskey - -	1,938	139 17 3 9	11,657 3 0	7 1/8 1/16
Condurrow - -	1,633	126 18 3 26	10,939 15 0	7 3/4
West Huel Treasury -	1,595	124 16 1 13	10,831 17 6	7 3/4 1/16
East Huel Crofty -	1,771	119 6 0 6	10,177 19 0	6 3/4
Holmbush - -	2,122	117 7 1 2	9,389 19 6	5 1/2
Tywarwhaile - -	2,092	105 18 3 24	7,476 4 6	5 1/16
Levant - -	1,333	101 11 3 9	7,993 4 6	7 5/8
Tresavean - -	2,565	100 2 1 12	7,669 0 0	3 7/8 1/16
Marke Valley - -	2,021	93 5 0 18	7,630 17 6	4 5/8
East Pool - -	1,740	86 10 1 26	6,845 2 0	5
Carried forward -	140,859	10,194 11 2 16	844,660 16 0	

Copper sold by Public Ticketings, &c. in Cornwall during the year 1852—*continued.*

Mines.	Ore.	Copper.	Amount.	Produce.
	Tons.	Tons. cwts. qrs. lbs.	£ s. d.	
Brought forward -	140,859	10,194 11 2 16	844,660 16 0	
West Seton - -	885	76 1 3 23	6,622 18 0	8 1/2 1/16
Camborne Vean -	1,397	74 2 0 2	5,852 3 0	5 1/4 1/16
Treleigh Consols -	980	72 2 3 16	6,198 12 6	7 1/8
Creegbraws - -	1,220	66 14 0 17	5,665 17 6	5 1/8 1/16
Hingston Downs -	699	66 10 0 25	5,721 4 0	9 1/2
Botallack - -	629	60 18 0 16	5,036 10 6	9 1/8 1/16
Huel Clifford - -	618	48 0 1 14	4,294 5 6	7 1/4
West Fowey Consols -	551	47 9 1 3	3,951 8 6	8 1/8
Huel Tremayne - -	756	42 15 3 2	3,434 19 0	5 1/8 1/16
Dolcoath - - -	832	42 14 3 10	3,344 12 6	5 1/8
Huel Agar - -	652	42 8 3 27	3,404 5 0	6 1/8
Huel Arthur - -	483	39 17 2 7	3,559 9 0	8 1/4
Huel Comfort - -	1,158	39 10 2 21	2,900 3 6	3 1/8 1/16
Poldice - - -	568	38 15 0 6	3,258 5 6	6 1/4 1/16
West Alfred Consols -	623	35 17 3 17	2,952 12 6	5 1/4
West Basset - -	574	35 9 0 18	3,059 12 0	6 1/8 1/16
Huel Trebarvah - -	474	31 4 3 19	2,635 5 0	6 1/8 1/16
Huel Speedwell -	436	29 9 2 14	2,525 0 6	6 1/2
Crane and Bejawsa -	326	28 17 1 3	2,373 7 0	8 1/8
Gonamena - -	243	23 15 2 2	2,143 10 0	9 1/4
Prideaux Wood -	495	23 14 0 4	1,810 15 0	4 1/2
Huel Ellen - -	366	20 18 1 8	1,690 10 0	5 1/8 1/16
West Providence -	146	20 14 2 22	1,868 18 6	14 1/8 1/16
Tavy Consols - -	335	19 10 3 18	1,635 11 0	5 1/4 1/16
Trethellan - -	459	18 13 1 20	1,392 13 0	4 1/16
Carvannall - -	214	18 11 1 12	1,512 16 6	8 1/8 1/16
Huel Unity Consols -	272	17 18 1 21	1,414 7 6	6 1/8 1/16
Great Day United -	260	16 15 1 9	1,551 5 6	6 1/8 1/16
Trannach and Bosence -	196	16 8 0 20	1,359 4 0	8 1/8
Great Huel Alfred -	273	16 4 3 4	1,444 9 0	5 1/8 1/16
West Damsel - -	290	15 18 3 9	1,396 9 0	5 1/8
Huel Crebor - -	209	15 13 1 27	1,344 15 6	7 1/8
Hawks Point - -	349	15 8 3 0	1,203 12 0	4 1/8 1/16
West Jewell - -	162	15 0 1 25	1,207 14 0	9 1/2
Carried forward -	158,989	11,388 19 0 11	944,427 17 6	

Copper Ores sold by Public Ticketings, &c. in Cornwall during the year 1852—*continued.*

Mines.	Ore.	Copper.				Amount.			Produce.
	Tons.	Tons.	cwts.	qrs.	lbs.	£	s.	d.	
Brought forward -	158,989	11,388	19	0	11	944,427	17	6	
Callington Killy Bray -	289	14	18	2	20	1,175	7	6	5 1/8 1/16
North Downs - -	222	14	15	2	27	1,333	10	0	6 5/8 1/16
Pembroke and East Crinnis	265	13	9	0	2	1,103	2	0	5 1/16
East Huel Leisure -	315	13	3	3	21	907	16	0	4 1/8 1/16
Huel Franco - -	244	12	15	3	4	1,090	4	0	5 1/4
North Huel Damsel -	165	12	12	0	16	1,215	16	6	7 5/8
East Seton and Huel Maud	195	12	11	1	24	1,019	1	6	6 3/8 1/16
Huel Bedford - -	267	10	11	3	24	742	14	6	4
Boscaswell Downs -	123	10	9	1	13	877	3	6	8 1/8
Huel Vyvyan - -	178	10	5	1	6	777	7	6	5 1/4
Huel Russell - -	181	10	4	3	10	763	9	0	5 5/8 1/16
Huel Busy - -	211	10	4	2	15	791	13	6	4 7/8
West Huel Alfred -	154	9	6	1	4	847	8	0	6
Huel Maiden - -	112	8	16	2	16	748	4	0	7 1/8
Huel Jewell - -	142	8	3	1	3	668	12	6	5 1/4
Hawk Moor - -	119	7	13	3	4	637	12	0	6 7/8 1/16
East Croundale - -	72	7	9	3	16	719	5	6	10 3/8 1/16
Huel Squire - -	58	6	13	3	22	573	18	6	11 1/8 1/16
Devon and Courtney -	70	6	10	0	5	570	4	0	9 1/4
Huel Brewer - -	116	6	7	0	22	573	8	6	5 1/8
St. Aubyn and Grylls -	75	6	4	2	8	564	16	0	8 1/2 1/16
Devon & Cornwall United	98	5	16	0	10	475	16	0	5 7/8 1/16
Great Huel Leisure -	111	5	12	0	3	415	4	6	5
North Huel Buller -	91	5	10	0	16	463	10	6	6
Boscundle - -	90	5	9	0	14	430	12	6	18 1/8 1/16
Tamar Slag - -	90	5	8	0	0	419	0	0	6
Huel Friendship and Prosper - -	124	5	4	3	17	384	0	6	4 1/4
Sundries - -	2,487	141	9	3	7	11,258	18	0	5 5/8 1/16
Total -	165,593	11,776	17	2	24	975,975	14	0	Mean 7 1/8

Copper Ore sold in Swansea by Public Ticketings and Private Contract in the year 1852.

Mines.	Ore.	Copper.	Amount.	Prod.
	Tons.	Tons. cwts. qrs. lbs.	£ s. d.	
Cobre	11,106	2,033 11 1 21	191,699 6 0	18¼ 1/16
Cuba	3,799	701 7 0 3	66,663 2 6	18⅜ 1/16
Bearhaven	5,692	591 0 3 10	54,687 19 6	10⅜
Kapunda	889	390 13 2 7	39,391 19 0	43/8 1/16
Knockmahon	3,471	315 11 1 0	29,285 14 0	9 1/16
Santiago	1,272	231 3 0 6	22,558 11 0	18⅛ 1/4
Copiapo	892	176 15 2 27	16,715 9 6	19¾ 1/4
Kaw aw	209	68 3 2 0	6,550 15 6	32⅝
Baltimore	266	45 4 0 21	4,198 19 0	17
Montreal	246	38 0 1 15	3,855 3 6	15⅜ 1/16
Kanmantoo	169	31 7 0 0	3,290 17 6	18½ 1/16
Ballymurtagh	556	26 1 2 5	2,266 9 6	4⅜ 1/16
Gyfron	212	25 18 2 25	2,397 19 0	12½
French	524	24 19 3 10	2,207 1 0	4⅜
Spanish	410	24 7 0 17	2,146 4 0	5/8 1/16
Waterloo Slag	464	21 6 0 16	1,709 15 6	4½ 1/16
Australian	113	19 16 3 0	1,967 14 0	17⅛ 1/16
Sydney	120	17 1 2 14	1,477 11 6	14½
Holyford	89	16 18 1 19	1,802 5 0	19
Severn	25	8 18 0 16	831 11 0	35⅝
Lackamore	140	8 14 0 14	794 8 0	6⅛ 1/16
Creetoun	110	8 5 0 22	759 18 6	7⅛
Wallah Wallah	35	7 10 3 22	726 17 0	21⅛ 1/16
Glo'ster Slag	49	7 1 1 4	640 17 0	14⅜
Molland	100	6 14 2 21	627 15 6	6¼
Dyliffe	72	6 1 0 13	566 3 0	8⅜ 1/16
Connorree	22	5 19 1 10	573 2 0	27
West Kaw aw	64	5 16 3 5	532 16 0	9⅛
London	11	5 10 0 0	541 15 0	50
Cronebane	25	5 1 3 10	493 10 6	20⅜
Sundries	502	26 17 0 17	2,353 6 0	5¼ 1/16
Total	31,654	4,901 18 3 6	464,314 16 0	Mean 15⅛

COPPER imported into the United Kingdom in 1852.

Ore.	Regulus.	Cast Copper.	Old Copper.	Bars, Rods, &c.	Plates, Coins.	Value.
Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	£ s. d.
37,817 13	5,226 0	2,188 6	968 0	2,993 8	23 1	19,234 10 6

Of this imported Copper the following countries furnished the largest quantities:—

	Ore.	Regulus.	Cast Copper.	Bars or Rods.
	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.
South Australia	8,581 18	401 10	628 13	372 4
New South Wales	115 4	242 0	3 5	0 19
Victoria	572 13	—	—	—
British North American Colonies	641 7	—	—	—
Cuba	17,661 17	—	—	—
Chili	5,569 7	3,684 15	1,098 4	944 18
Peru	580 18	54 1	11 17	90 7
Bolivia	306 9	—	—	—
West Coast of Africa	53 14	—	—	—
France	681 6	277 9	—	100 18
Spain	1,934 13	—	180 7	13 12
Italy	144 15	—	10 19	44 0
Norway	165 17	—	0 11	118 10
Russia	—	—	225 12	1,041 10
Tunis	100 0	—	—	—
British Territories in the East Indies	119 5	224 0	—	—
United States of America	2 11	324 2	—	1 10

Of this quantity there was re-exported—

Ore.	Cast Copper.	Old Copper.	Bars and Rods.	Value.
Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	£ s. d.
49 15	368 7	310 18	678 4	15,099 0 0

BRITISH COPPER exported.

Ore.	Bricks, Pigs, &c.	Coin.	Sheet, Nails, Yellow Metal.	Wire.	Wrought Copper of other Sorts.	Total.
Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.	Tons. cwts.
0 15	5,913 6	47 17	10,094 7	121 4	759 7	16,936 1

TIN.

PRODUCE of TIN ORE in CORNWALL and DEVON in 1852.

9,674 Tons.

PRODUCE of some of the principal TIN MINES in the counties of DEVON and CORNWALL for the year ending 1852.

Mines.	Tin Ore.		Mines.	Tin Ore.	
	Tons.	cwts.		Tons.	cwts.
Balleswidden	405	2	Brought forward	2,832	12
Great Polgooth	355	10	Huel Bal	10	14
Polberro	222	5	St. Blasey Consols	9	14
Drake Walls	218	16	Balnoon do.	8	9
Lewis	204	11	East Margaret	7	7
Porkellis United	190	12	Millpool	7	4
Tincroft	159	0	Carbona	6	18
Huel Lovel	130	4	Tavistock United	6	15
Georgia Consols	125	7	Trevena	5	9
Charlestown United	80	17	Prince Albert Consols	5	1
Boscundle	67	8	South Frances	5	0
Tremayne	63	8	Huel Robins	4	9
Rix Hill	60	13	Great Huel Baddern	4	1
Levant	57	11	Creeg Braws	4	0
Rocks and Treverbyn	56	1	South Speed	3	8
West Huel Towan	49	0	East Balleswidden	3	6
Yeoland Consols	44	15	Huel Kitty (Uny Lelant)	3	5
Condurrow	44	11	Grambler St. Aubyn	3	1
West Providence	40	4	Huel Friendship	3	0
Trevelyan	35	13	Bosom	2	15
Boscean	23	2	West Downs	2	10
Chyprase Consols	21	11	East Halamanning	2	10
Huel Basset	21	0	Huel Anna (Water Stamp)	2	1
East Pool	20	16	Huel Augusta	1	7
Huel Sidney	19	19	West Polgooth and Hewas	1	5
Huel Carne (St. Just)	19	0	Teter Tavy and Mary Tavy	1	2
Par Consols	18	3	Trebell Consols	1	2
Bottle Hill	18	0	Huel Stanley	1	1
Birch Tor and Vitifer	15	4	Union Tin	1	0
Huel Unity	11	7	Lamtrerove	0	16
Great Beam	11	4	Park Wynn	0	13
South Charlotte	11	0	Castle Dinas	0	9
Devon United	10	18			
Carried forward	2,832	12	Total	2,952	4

TIN imported in the year ending 1852.

Countries from which imported.	Tin.				Tin Ore and Regulus.			
	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.
Hanseatic Towns	11	5	1	5	—			
Holland	1,307	19	2	4	—			
Belgium	0	15	3	16	—			
Channel Islands		—			1	0	0	0
France	42	5	1	22	9	4	1	19
Portugal		—			11	0	2	6
British Territories in the East Indies, exclusive of Singapore and Ceylon	225	5	2	10	—			
Singapore	750	12	1	18	—			
China (including Hong Kong)	15	3	1	23	—			
Chili	6	1	1	3	—			
Peru	12	5	2	17	1	5	2	12
Other Parts	0	8	1	13	—			
Total Import	2,372	2	3	19	22	10	2	9

TOTAL of TIN exported in the year 1852.

	Tons.	cwts.	qrs.	lbs.
British Tin	941	12	0	0
Foreign Tin	433	3	0	0

LEAD.

PRODUCE of LEAD ORE, LEAD, and SILVER in the UNITED KINGDOM for the Year 1852.

Total of Lead Ore. — County.	COUNTY.	MINES.	Lead Ore Returns.	Lead Returns.	Silver.	Total of Lead. — County.
Tons.		ENGLAND.	Tons. Cwts.	Tons. Cwts.	ozs.	Tons.
	Cornwall	Callington	243 0	154 10	7,700	
		Huel Mary Anne	994 12	742 0	38,600	
		Huel Trelawney	971 19	721 0	33,906	
		North Huel Trelawney	13 0	9 10	260	
		Huel Trehane	506 0	375 0	22,000	
		Tregorden	9 0*	6 0		
		Herodscoombe	—			
		Herodsfoot	663 0	505 11	9,282	
		East Huel Rose	2,381 3	1,607 0	48,000	
		North Huel Rose	321 7	211 0	5,900	
		Cargol	70 12	40 0	1,800	
		Oxnams Lands	39 0	24 10		
		South Cargol	70 12	40 0	1,800	
		Charity Lands	—			
		Dean and Chapter Lands	—			
		Huel Penhale	7 0	5 0	50	
		Huel Golden Consols	586 0	409 5	7,700	
		Huel Rose	—			
		Holmbush	25 0	14 0½	640	6,220 6½
8,998 14		Great Callestick Moors	—			
		Huel Concord	—			
		Carthew Consols	16 10	11 10	120	
		Great Huel Baddern	628 0	447 0	9,400	
		Pentire Glaze	372 0	205 0	8,200	
		Nancekuke	338 0	220 0	8,300	
		Huel Albert	14 19	11 4		
		Huel Venton	4 10	3 7		
		Trefrew	29 0	22 0		
		Huel Constance	20 0	12 15	400	
		Treweme	1 15	1 6		
		Wheatley Blue	126 0	90 0	1,200	
		Huel Langford	7 10	5 12		
		Pentire Glaze	372 0	205 0		
		Trelogan	11 10	8 5		
		Tywarnhayle	57 0	41 0		
		Trefrew	20 0	15 10		
		Cubert United Silver Lead	70 0	50 0	750	
		Silver Valley and Huel, Brothers	8 15	6 11		
	Devonshire	Tamar	919 0	442 0	40,200	
		Huel Adams	70 0	38 10	680	
		East Tamar Consols	305 18	235 10	5,226	
		Huel Friendship	10 0	7 0		
		South Tamar Consols	950 8	684 16	41,328	1 873 11
2,921 19		South Molton Consols	—			
		Huel Exmouth	634 13	443 15	2,500	
		Huel Ex	—			
		Boringdon Consols	32 0	22 0	1,300	
	Carried forward		11,920 13	8,093 17½		

* To 5th May 1852, when the Mine stopped.

Produce of Lead Ore, Lead, and Silver in the United Kingdom for the Year 1852—*continued.*

Total of Lead Ore. County.	COUNTY.	MINES.	Lead Ore Returns.	Lead Returns.	Silver.	Total of Lead. County.
Tons.	Brought forward		Tons. Cwts. 11,920 13	Tons. Cwts. 8,093 17½	ozs.	Tons.
2,977 4	Devonshire—*continued.*	Boringdon Park	8 0	6 0		1,917 8
		East Boringdon	12 15	8 5		
		Wood Mine	3 10	2 12		
		True Blue	31 0	27 0	100	
	Cumberland	Browngill	234 17	164 4		
		Rampgill	200 13	140 7		
		Scaleburn	92 8	66 13		
		Carrs and Hanging Shaw	101 15	70 14		
		Capel Cleugh	297 18	209 8		
	Governor and Company Mines.	Small Cleugh	135 11	100 0		
		Middle Cleugh	49 17	35 1		
		Guddamgill	80 6	55 6		
		Long Cleugh	1,656 16	1,158 12		
		Bentyfield Sun Vein	48 9	34 2		
		Cowperdyke Heads	83 8	57 12		
		Tynebottom	56 12	34 17		
		Priorsdale	14 1	8 12		
		Bentyfield Sun, V. E. End				
		Brigal Burn	144 18	86 17		
		Cow Gap				
		Fore Shield				
		Flow Edge	3 8	2 5		
		Gutter Gill	6 15	4 14		
		Brownley Hill	156 16	109 5		
		Blagill Vein	57 16	41 11		
		Carrs West of Nent Vein	8 7	6 5		
		Black Syke	54 5	36 1		
		Hudgill Burn	154 0	111 5		
		Farnbury Vein				
		Grassfield	29 15	19 16		
		Galligill or Garrigill Syke	79 16	71 7		
6,452 7		Crag Green	2 7	1 13		4,518 8
		Tynehead	68 5	50 0		
		Force Cragg				
		Keswick Mine	179 0	137 0		
		Cross Fell Mine	88 0	68 0		
		Greenside	2,150 0	1,466 0		
		Holyfield	47 7	31 10		
		North Grain Cross Vein				
		West Gill Cross Vein				
		Nattrass Middle Vein	13 8	11 2		
		Nattrass North Vein	1 4	0 18		
		Coatlithe Hill	0 6	4 10		
		Fourdarque	16 7	12 5		
		Nentsbury Green	2 0	1 10		
		Nellgill Crop Vein	86 4	64 13		
		Park Grove Vein	5 9	4 1		
		Lee House Well	16 3	12 2		
		Clargill Head	7 2	5 6		
		Peat Stack Hill	17 5	14 0		
		Sunny Side	0 10	7 0		
		Slote	3 3	2 4		
		Dowke Burn West End				
	Carried forward		18,428 5	12,656 2½		

Produce of Lead Ore, Lead, and Silver in the United ingdom for the Year 1852—*continued.*

Total of Lead Ore. County.	COUNTY.	MINES.	Lead Ore Returns.	Lead Returns.	Silver.	Tons of Lead. County.
Tons.			Tons. Cwts.	Tons. Cwts.	ozs.	Tons.
	Brought forward		18,428 5	12,656 2½		
	Cumberland—*continued.*	Rodderup Fell	1,200 0	811 0		
		Low Birchy Bank	2 18	2 0		
		Cald Beck Mine	541 0	385 0	600	
		Wood End	8 10	6 0		
		Smittergill Foot Mine	0 12	0 9		
		Thorngill East Vein	8 7	6 5		
		Thorngill West End	13 6	7 17		
		Park Grove Sun Vein				
		Dry Burn				
8,410 17		Howgill Syke	6 14	4 13		5,877 15
		Windy Brow North Vein				
		Claregillhead				
		Smittergill Head Mine	15 9	11 0		
		Clargill Burn	1 9	1 3		
		Gold Scope	18 5	14 0	70	
		Yewthwaite	130 0	101 0		
		Blencathara	4 0	3 0		
		Skiddaw	8 0	6 0		
	Durham and Northumberland.	East and West Allendale and Weardale	13,840 0	10,313 0		
	Teesdale Mines.	Coldberry Mine	269 18	3,446 0		
		Coldberry Skears Mine	203 16			
		Lodge Syke Mine	378 18			
		Maunorgill Mine	82 6			
		Little Eggleshope Mine	2,133 0			
		Ashgill Head Mine	690 6			
		Red Groves Mine	170 8			
		High Skears Mine	163 4			
		New Streak and Broadley Hill	32 14			
		Pike Law Armstrong Vein	18 6			
		Green Hurth Mine	148 19			
		Grasshill Mine	31 5			
		Trough Head Mine	45 6			
		Willy Hole East Side	386 8			
21,594 3		Sundry Mines	31 7			15,978 11
		Flakebrigg	142 2	89 18		
		Flushamie	4 4	3 3		
		High Dyke	2 8	1 16		
		Silver Tongue				
		Derwent Mines	1,133 0	875 0		
		Stanhope Burn	323 6	218 16		
		Hallywell	27 11	20 0		
		Lanehead	28 16	20 10		
		Allergill	2 9	1 18		
		Bollihope	36 0	22 0		
		Fallowfield	101 5	80 0		
		Whitefield Mines	13 4	8 10		
		Captain Clough	43 0	32 0		
		Brandon Walls	100 0	76 0		
		Calves	13 8	9 0		
		Mellowburry				
		Settlingstones	960 0	735 0		
		Harehope Gill	37 9	26 0		
	Carried forward		41,980 18	29,994 0½		

Produce of Lead Ore, Lead, and Silver in the United Kingdom for the Year 1852—*continued.*

Total of Lead Ore. County.	COUNTY.	MINES.	Lead Ore Returns.	Lead Returns.	Silver.	Tons of Lead. County.
Tons.			Tons. Cwts.	Tons. Cwts.	ozs.	Tons.
	Brought forward		41,980 18	29,994 0½		
499 0	Westmorland -	Dufton and Silverband, Hilton, Murton, and Hardshins - - -	499 0	380 2		380 2
8,425 0	Derbyshire -	Eyam Mines - -	87 0	65 0		5,448 0
		Return from Smelters -	8,338 0	5,383 0		
	Shropshire -	Snail Beach - -	2,840 0	2,128 0		
		Bat Holes - -				
2,934 10		Bog Mine - - -	26 0	19 10		2,201 3
		Rorington - - -	68 10	53 13		
		White Grit - -				
100 0	Somersetshire	Mendip Hills - -	100 0	70 0		70 0
	Yorkshire -	Swaledale and Arkendale -	4,765 0	3,240 0		
		Hurst - - -	426 0	264 0		
		Wensleydale - -	2,670 0	1,386 0		
		Cononley - - -	554 0	381 12		
		Grassington (including Yarnbury and Coalgrove Beck) - -	1,530 10	1,036 0		5,720 2
8,472 1		Pately District - -	950 0	632 10		
		Kettlewell and Coniston Liberty - -	180 0	120 0		
		Lunehead - -	32 0	24 0		
		Silverband - -	34 11	22 0		
		Total -	62,411 9	43,813 7½		
		WALES.				
	Cardiganshire	Lisburne Mines - -	3,186 0	2,293 0	8,972	
		Cwm-ystwyth - -	1,075 0	784 0	2,350	
		Esgair-Llee - - -	65 3	48 0		
		Cwm-sebon - -				
		Llawr-cwmbach - -	4 0	2 16		
		Llanfair Clydogau - -				
		Goginan - - -	556 0	389 0	10,892	
6,322 1		Llettyhen - -	27 0	19 0		
		Nant-y-creiau - -				4,571 9
		Cefn-cwm-brwyno -	190 0	143 0		
		Bwlch Consols - -	205 0	157 10	3,925	
		Nanteos - - -	452 0	334 10		
		Coedmawr Pool - -	62 0	49 0		
		Court Grange - -	171 0	120 0	3,600	
		Grogwinion - -	23 18	16 8		
		Brynarian - - -	31 0	23 10		
		Cwm-erfin - - -	259 0	180 0	1,360	
		Darren - - -	15 0	11 15	275	
	Carried forward		6,322 1	4,571 9		

Produce of Lead Ore, Lead, and Silver in the United Kingdom for the Year 1852—*continued.*

Total of Lead Ore. County.	COUNTY.	MINES.	Lead Ore Returns.	Lead Returns.	Silver.	Total of Lead. County.
Tons.			Tons. Cwts.	Tons. Cwts.	ozs.	Tons.
	Brought forward		6,322 1	4,571 9		
	Cardiganshire —*continued.*	East Darren	483 0	347 0	6,940	
		Aberyfrwydd				
		Esgair Mwyn	56 0	42 10	200	
		Ceregwynon	12 16	9 0		
		Cwm Darren	10 9	7 6	140	
		Cambrian				
		Bryntail	63 0	44 0	120	
7,370 10		Bronberllan	4 4	3 3		5,305 8
		Bronfloyd	10 0	7 10	70	
		Graig-goch	96 0	71 0		
		Craigymwyn				
		Alt-y-crib	64 0	42 10		
		Level Newydd	75 0	57 0		
		Frongoch	90 0	40 0		
		Pen-y-cefn	64 0	48 0		
		Melin-Llyn-pair	20 0	15 0	120	
	Carnarvonshire	Portmadoc				
	Carmarthenshire	Nant-y-Mwyn	800 0	624 8		
955 0		Vale of Towy	137 0	102 15		740 3
		St. David	18 0	13 0		
170 0	Denbighshire	Minera Mines	170 0	127 0		127 0
	Flintshire	Talargoch { Maes-yr-erwddu / Coetia Llys }	1,431 10	1,087 0	9,800	
		Fronfownog	107 0	79 0	400	
		Hendre	153 10	118 0	500	
		Maes-y-safn	685 0	521 0	2,000	
		Pen-yr-henblas	236 0	177 0	1,200	
		Long Rake	16 5	12 0	40	
		Milwr	348 0	265 0	1,500	
		Penybryn	58 0	43 5	160	
		Dingle and Deep Level	665 0	502 0	2,000	
		Parry's Mines				
		Westminster Mines	1,845 0	1,448 0	2,900	
		Halkin Hall				
6,250 5		Bodelwyddan	109 0	64 0		
		Belgrave				4,756 5
		Bryn-steddfod	40 0	30 10		
		Orsedd	13 10	10 0	80	
		Jamaica	330 0	240 0	1,200	
		Bwlchgwyn	90 15	70 0		
		Cheney Rake	35 5	26 0	100	
		Aberdune				
		Peoples Brothers	22 5	16 15		
		Axton				
		Pant-du				
		Pant-y-celyn				
		Garrigboeth	30 0	21 0		
		Pant-y-groes				
		Pant-y-pwlldwr	34 5	25 15	100	
	Carried forward		14,745 15	10,928 16		

Produce of Lead Ore, Lead, and Silver in the United Kingdom for the Year 1852—*continued.*

Total of Lead Ore. County.	COUNTY.	MINES.	Lead Ore Returns.	Lead Returns.	Silver.	Tons of Lead. County.
Tons.			Tons. Cwts.	Tons. Cwts.	ozs.	
	Brought forward		14,830 19	10,995 14		
	Flintshire—*cont.*	Pant-y-ffryth	167 10	127 15	1,000	
		Strong Croft				
		Talacre	322 0	248 0	1,950	
		Holywell Level	142 0	106 5	200	
8,565 5		Lloc	196 0	161 10	1,600	6,519 15
		Merllyn	925 0	707 0	5,600	
		Panty-mwyn or Mold Mines	267 0	200 0	1,200	
		Plantation	29 0	22 10	250	
		Sundries under 10 Tons	266 10	190 10		
					800	
	Montgomery-shire.	Chirk Castle	81 0	64 0		
		Cae-conroy	53 0	41 15	250	
		Rhos-wydol	166 0	126 10	620	
		Dwn-gwm or Dyfngwm, Craig Rhiwarth	25 0	19 5		
					70	
1,175 0		Bryntail	18 0	13 0		906 10
		Gorn	19 0	14 0		
		Machynlleth, including Delife	750 0	580 0		
					3,300	
		Nantmelyn				
		Pen-y-clyn				
		Llanerchyrew	63 0	48 0		
	Merionethshire	Barmouth, Port of				
		Llanrwst	115 0	88 0		
28 5		Cowarch				21 5
		Tyddyingbuddel				
		Dolgelly				
		Eagles Rock				
		Bwich-y-cyran	28 5	21 5		
		Total	18,379 0	13,708 1		
		IRELAND.				
	Clare	Kilbricken	72 0	40 0	4,000	
472 0		Ballyhicky				350 0
		Annaglough	400 0	310 0		
1,844 4	Down	Newtownards	1,795 0	1,420 0		1,460 0
		Conlig	49 4	40 0		
18 0	Cork	Bantry	18 0	10 0	70	10 0
53 0	Galway	Glengola	50 0	39 5	140	
		Galway Mines	3 0	1 19		41 4
52 10	Louth	Dundalk	52 10	38 15		38 15
	Carried forward		2,439 14	1,899 19		

Produce of Lead Ore, Lead, and Silver in the United Kingdom for the Year 1852—*continued.*

Total of Lead Ore. County.	COUNTY.	MINES.	Lead Ore Returns.	Lead Returns.	Silver.	Tons of Lead. County.
Tons.	Brought forward		Tons. Cwts. 2,439 14	Tons. Cwts. 1,899 19	ozs.	Tons.
796 0	Tipperary	Shallee	287 0	172 4	12,000	517 14
		E. Shallee	433 0	295 0		
		W. Shallee				
		Gorteenadiha	76 0	50 10	300	
	Monaghan	Bond and Newry				
	Wicklow	Glenmalure	201 0	144 5	950	
1,334 0		Luganure	1,057 0	661 0	4,822	855 15
	Wexford	Barristown				
		Total	4,493 14	3,222 18		
		SCOTLAND.				
	Ayrshire	Afton Lead Mines				
270 0	Argyleshire	Strontian Mines	270 0	208 0	1,000	208 0
	Dumbartonshire	Dumbarton				
	Kirkcudbrightshire.	Cairnsmore	447 0	340 0	1,200	
1,306 0		Woodhead	282 0	193 2		968 7
		Black Craig	577 0	435 5		
	Perthshire	Breadalbane				
1,097 0	Lanarkshire	Lead Hills Mine	1,097 0	585 0		585 0
826 0	Dumfrieshire	Wanlock head	826 0	620 0	4,350	620 0
		Total	3,499 0	2,381 7		
		ISLE OF MAN,				
	Isle of Man	Isle of Man Mining Company	1,600 0	1,224 0	12,224	
		Laxey	800 0	600 0	32,400	
		South Manx	15 0	11 5	40	
		Douglas				
		Total	2,415 0	1,835 5		
		The Welsh ticketings include also the following Foreign ores:—				
		South Australian	30 0	21 0	300	
		Arkansas	8 0	6 0		
		Total	38 0	27 0		

TABLE showing the TOTAL QUANTITY of LEAD ORE raised and smelted in the UNITED KINGDOM in 1852.

	Lead Ore.		Lead.	
	Tons.	Cwts.	Tons.	Cwts.
England - - -	62,411	9	43,813	7½
Wales - - -	18,379	0	13,708	1
Foreign Ores - -	38	0	27	0
Ireland - - -	4,493	14	3,222	18
Scotland - - -	3,499	0	2,381	7
Isle of Man - -	2,415	0	1,835	5
Total - -	91,236	3	6,4987	18½

LEAD ORE and LEAD IMPORTED and EXPORTED in 1852.

IMPORTED.

	Tons.	Cwts.
Lead Ore - - - -	802	16
Pig and Sheet Lead - - -	13,257	2
White Lead - - - -	63	15

EXPORTED.

	Tons.	Cwts.
Lead Ore - - - -	195	0
Pig and Sheet Lead - - -	18,641	0
Shot - - - - -	1,355	0
Litharge - - - -	477	13
Red Lead - - - -	1,181	15
White Lead - - - -	1,731	1
Foreign Lead re-exported - -	2,966	14

SILVER.

ESTIMATE of SILVER produced from the MINES of GREAT BRITAIN and IRELAND in 1852.

County.	Average proportion of Silver in each Ton of Lead.	Ounces of Silver in each district.	Value at Five Shillings per ounce.
	Ounces.		£
Cornwall	35	250,008	62,502
Devonshire	40	91,340	22,835
Cumberland	9	52,893	13,223
Durham, Northumberland, and Westmorland	12	191,736	47,934
Cardiganshire, Carnarvonshire, and Carmarthenshire	15	91,680	22,920
Flintshire and Denbighshire	7	47,138	11,784
Montgomeryshire and Merionethshire	6	5,562	1,390
Ireland	10	32,220	8,055
Scotland	8	19,048	4,762
Isle of Man	20	36,700	9,675
		818,325	205,080

The above is only to be regarded as an approximation to the actual produce. Messrs. Walker and Company have very kindly furnished a large number of the returns of Silver, which are appended to the Mines in the foregoing list, and many of the Proprietors of the Mines themselves have communicated the exact produce of Silver from their Lead Ores. Mr. John Taylor has given an estimate of the average proportion of Silver from each County, which his intimate acquaintance with the mining operations of the Country enables him to do with great accuracy, and this has been employed in the determination of the quantities above given, where necessary.

GENERAL SUMMARY.

PRODUCE of the principal COPPER MINES for the Five Years, 1848–52, both inclusive.

Mines.	Ore.	Copper.	Amount.
	Tons.	Tons. cwts. qrs. lbs.	£ s. d.
Devon Great Consols	88,963	8,192 14 1 22	545,648 13 0
Cairn Brea	44,115	3,964 14 3 2	267,871 1 6
Par Consols	35,672	3,407 18 2 15	228,618 2 0
Consolidated Mines	35,446	2,709 19 0 6	183,733 17 6
United Mines	51,896	3,330 16 1 22	226,707 15 6
Fowey Consols	28,311	2,496 19 0 20	165,751 18 0
Huel Seton	27,202	1,858 11 0 20	125,684 13 6
North Roskear	23,976	1,873 13 3 9	127,090 2 0
West Caradon	19,859	2,172 10 0 6	152,388 13 0
South Caradon	15,089	1,570 6 0 17	109,166 16 0
North Pool	30,181	1,819 16 0 25	118,956 10 0
Huel Friendship (East)	12,283	1,317 11 2 9	91,999 15 0
South Huel Francis	12,199	1,360 15 1 14	97,396 1 0
Tincroft	33,415	1,927 6 1 23	125,983 14 0
East Huel Crofty	13,616	951 19 3 22	63,070 10 6
Tresavean	14,152	726 3 0 0	45,207 1 0
Camborne Vean	11,860	786 11 2 3	50,995 2 6
South Huel Basset	21,116	1,942 13 0 21	141,200 19 0
Levant	9,220	785 7 2 22	50,330 3 0
Treviskey	11,611	1,029 0 2 13	72,245 10 0
Bedford United Mines	7,726	713 13 0 8	49,753 18 0
Treleigh Consols	5,992	458 12 2 10	31,584 7 6
Penam Saint George	12,029	652 0 2 18	49,741 1 0
Tywarnhaile	20,737	1,210 8 3 4	77,226 16 0
Huel Comfort	10,342	407 11 2 3	23,046 18 0
Condurrow	8,047	579 18 2 3	39,995 10 0
Dolcoath	5,030	343 7 0 17	22,664 17 6

COPPER.

From English Mines.

	Ore.	Copper.				Value.		
	Tons.	Tons.	cwts.	qrs.	lbs.	£	s.	d.
1848	147,701	12,241	19	2	5	720,090	17	0
1849	146,326	11,683	13	0	22	763,614	19	0
1850	155,025	12,253	10	2	21	840,410	16	0
1851	150,380	11,807	8	2	18	782,947	8	6
1852	165,593	11,776	17	2	24	975,975	14	0
	765,025	59,943	9	3	6	4,083,039	14	6

From Irish, Welsh, and Foreign Mines, sold at Swansea.

	Ore.	Copper.				Value.		
	Tons.	Tons.	cwts.	qrs.	lbs.	£	s.	d.
1848	49,363	8,672	18	0	15	562,418	11	0
1849	43,593	7,540	2	3	22	564,585	16	0
1850	41,586	7,108	8	1	11	549,258	3	6
1851	37,241	6,015	0	2	17	463,953	3	0
1852	31,654	4,901	18	3	6	464,314	16	0
	203,437	34,238	8	3	15	2,604,530	9	6

Total of Copper smelted at Swansea during the above Five Years.

	Ore.	Copper.				Value.		
	Tons.				lbs.	£	s.	d.
English Mines -	765,025	59,943	9	3	6	4,083,039	14	6
Foreign, Irish, and Welsh Mines -	203,437	34,238	8	3	15	2,604,530	9	6
	968,462	94,181	18	2	21	6,687,570	4	0

Copper imported.

	Ore.	Regulus.	Copper.	Value.
	Tons. cwts.	Tons. cwts.	Tons. cwts.	£ s. d.
1848	50,053 2	124 2	1,749 13	9,200 9 5
1849	46,237 4	667 12	2,169 5	25,338 11 10
1850	40,388 6	5,473 12	5,824 13	35,946 13 6
1851	35,683 18	6,442 5	5,590 7	30,073 13 9
1852	37,817 13	5,226 0	6,172 16	19,234 10 0

British Copper exported.

	Ore.	Copper.
	Tons. cwts.	Tons. cwts.
1848	—	13,466 7
1849	—	27,480 3
1850	150 10	21,307 13
1851	1 3	17,555 11
1852	15 0	16,936 1

TIN.

Produced in Britain.

	Tons.
1848	10,176
1849	10,719
1850	10,383
1851	9,455
1852	9,674

Tin imported.

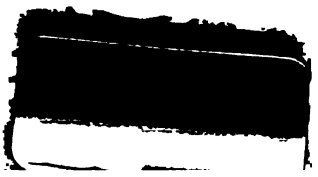
	Tin.		Tin Ore.	
	Tons.	cwts.	Tons.	cwts.
1848	298	15	33	18
1849	1,791	2	7	2
1850	1,685	11	—	
1851	2,387	1	5	0
1852	2,372	2	22	10

British Tin exported.

	Tons.	cwts.	qrs.	lbs.
1848	1,797	5	3	10
1849	1,764	12	0	5
1850	1,588	1	2	17
1851	1,011	0	0	0
1852	941	12	0	0

LEAD.

Lead Ore and Lead from the Mines of the United Kingdom.

	Lead Ore.	Lead.
	Tons.	Tons.
1848	77,864	54,853
1849	86,773	58,703
1850	93,043	64,527
1851	101,964	65,110
1852	91,236	64,987

BOUND
UNIVERSITY OF MICHIGAN
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